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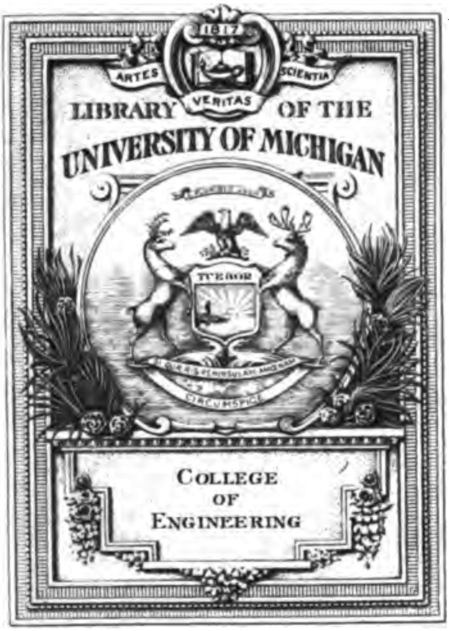

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ANNUAL REPORT

9

UPON THE

IMPROVEMENT OF THE OHIO, MONONGAHELA, AND WABASH RIVERS,

IN CHARGE OF

W. E. MERRILL,
MAJOR OF ENGINEERS, BVT. COLONEL, U. S. A.;

BEING

APPENDIX R

OF THE

ANNUAL REPORT OF THE CHIEF OF ENGINEERS FOR 1876.

U.S. Engineer dept.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1876.

[EXTRACT FROM THE ANNUAL REPORT OF THE CHIEF OF ENGINEERS TO THE SECRETARY OF WAR.]

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., October 21, 1876.

* * * * * * *

IMPROVEMENT OF THE OHIO, MONONGAHELA, AND WABASH RIVERS.

Officer in charge Maj. W. E. Merrill, Corps of Engineers, having under his immediate orders Lieut. F. A. Mahan, Corps of Engineers.

1. *Improvement of the Ohio River.*—The contracts outstanding at the end of the last fiscal year were for the extension of the French Island dike; the completion of the dike at Evansville; the completion of a dike at Henderson Island, and the construction of a dam at the same place.

The French Island dike has been extended 1,518 feet, making a total length of 3,498 feet, or two-thirds of a mile. The result thus far has been quite satisfactory.

Very little was done at the Evansville dike beyond repairing damages and stopping a threatened scour below the shore-end. The flood of August so reduced the working-season that no work could be done on the proposed extension of 500 feet. The dike has done excellent service, and it is believed that when extended as proposed the Evansville bar will be entirely removed. Its present length is 1,525 feet.

The dike at Henderson Island has been completed, its total length being 1,900 feet. It has had an excellent effect on the bar on which it is built, but it has but little effect on the bar at the foot of the island, and it will probably be necessary to build another dike about 4,000 feet below the present one in order to remove this obstruction.

The dam behind Henderson Island has been repaired and completed. Its length is 620 feet, and its width 50 feet. It has fully accomplished its object of forcing all the water, at stages below 6 feet, to pass alongside of the dike.

The snag-boat E. A. Woodruff has been completed and put in commission. From the 8th to 30th of June, she had removed 123 snags and 2 wrecks, and is still at work doing good service to Ohio River commerce.

The Government dredges Ohio and Oswego have been in constant service, except during the months of ice and high water. During the fiscal year they have dredged the following from the channel:

	Cubic yards.
Saw Mill Run	19,201
Brunót's Island	25,173
Deadman's Island	22,807
White's Bar	8,329
Hay's Bar	29,961
Deadman's Island	15,330
Raccoon Island	6,940
Total	127,741

134917

The average cost per cubic yard during the year 1875 was 17 cents.

The dredges also removed from the channel 11 wrecks and 6 snags.

Forty-three snags and one rock-heap were removed by special contract during the autumn of 1875, before the snag-boat was completed.

During the fiscal year two contracts were made for the removal of wrecks in the Lower Ohio. One contractor failed to procure bondsmen, and did no work. The other, at the close of the fiscal year, had removed 3 wrecks, and since June 30, he has completed his contract.

No work was done on the first movable dam on the Ohio, (for which $100,000 was allotted,) because the legislature of Pennsylvania failed to pass an act giving cession of jurisdiction and power to condemn the necessary land. The report contains an account of the steps taken to secure the required legislation.

For the report of the board of engineer officers convened to examine and report upon and which adopted the plan and location of this dam, as proposed by Major Merrill, see Appendix R 2.

During the early part of 1876 Lieutenant Mahan, whilst on leave of absence, made a special examination of the various movable dams now in operation in France. In consequence of the information he obtained, (see Appendix R 1,) and of information from other sources, it is now proposed by the officer in charge to replace the maneuvering-boat by a service bridge, and to crown the high wier with a Poirée dam, using either needles or the gates invented by M. Boulé, as may be subsequently determined. A new estimate for this dam is therefore submitted by Major Merrill. Its total cost, including the dam behind Davis Island, is put at $465,000, of which $99,845 is now on hand.

The removal of the dam at Cumberland Island is strongly recommended by the officer in charge, on the ground that it is a serious injury to the navigation of the Ohio, and that the reasons that originally caused its construction no longer exist.

The officer in charge submits the following estimate for the fiscal year 1877-'78:

For snag-boat, dredges, and office	$100,000 00
For riprap, dams, and dikes	185,000 00
For completion of movable dam at Davis Island	365,000 00
Total amount required	650,000 00

A translation from the *Annales des ponts et chaussées*, containing a full account of the modification in the needle-dams invented by M. Boulé, accompanies this report as Appendix R 3.

Amount available July 1, 1875	$274,611 40
Amount expended during fiscal year ending June 30, 1876	157,590 45
Amount available July 1, 1876, including $8,688.16 due on contracts, &c.	117,020 95
Amount appropriated by act approved August 14, 1876	175,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1878	650,000 00

(See Appendix R 1.)

2. *Improvement of the Monongahela River.*—The work on this river consists in completing lock and dam No. 9 at Hoard's Rocks, West Virginia, ninety-four miles above Pittsburgh, and eight and a half miles below Morgantown.

The lock has been finished except the miter and lift walls, which were not embraced in the contract. For reasons set forth at length in the report of the officer in charge, an additional appropriation of $20,000 will be required to complete this lock and dam.

Estimate for the fiscal year 1877-'78.

For completion of lock and dam at Hoard's Rocks	$20,000 00
For lock at Laurel Run, (omitting miter-walls, gates, and valves)	60,000 00
Total amount required	80,000 00

Amount available July 1, 1875	101,286 09
Amount expended during fiscal year ending June 30, 1876	63,471 48
Amount available July 1, 1876, including $2,601.16 due on contracts, &c.	37,814 61
Amount that can be profitably expended in fiscal year ending June 30, 1878	80,000 00

(See Appendix R 4.)

3. *Improvement of the Wabash River.*—The outstanding contracts at the beginning of the fiscal year were for clearing out the Little Cut-off, for closing the New Harmony Cut-off by a dam, and for excavating a channel at Warwick's Ripple.

The contract at Little Chain was completed.

At New Harmony the dam was only partly built when the season closed. Some damage was done to it during the winter, but this has been repaired, and the dam will probably be finished by the end of the year.

At Warwick's Ripple no work of excavation was done during the last season, as the contractor failed to get his coffer-dam dry. He is again at work, but thus far has done but little. The prospect of finishing the work by the close of the present season is unfavorable.

Estimate for fiscal year 1877-'78.

For rebuilding Grand Rapids lock	$130,000 00
For engineering and contingencies	15,000 00
Total amount required	145,000 00

Amount available July 1, 1875	49,917 03
Amount expended during fiscal year ending June 30, 1876	15,802 15
Amount available July 1, 1876, including $271.88 due on contracts	34,114 88
Amount appropriated by act approved August 14, 1876	70,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1878	145,000 00

(See appendix R 5.)

EXAMINATIONS AND SURVEYS FOR IMPROVEMENT.

To comply with provisions of the act of March 3, 1875, Major Merrill was charged with the completion of the surveys begun under the act of June 23, 1874, for the extension of the *Chesapeake and Ohio Canal from Cumberland, Maryland, to the headwaters of the Youghiogheny River.* The final report was transmitted to Congress at its last session, and printed in H. R. Ex. Doc. No. 137. (See Appendix R 6.)

Also with the *survey of Monongahela River from Morgantown to Fairport, West Virginia,* and an *examination of the Louisa Fork of Sandy River from the mouth of Dismal, in Buchanan County, Virginia, to Piketon, Kentucky,* the results of which were transmitted to Congress in reports printed in H. R. Ex. Doc. No. 91. (See Appendixes R 7 and R 8.)

And also with an examination of *Allegheny River below Freeport, Pennsylvania,* and the *survey of Allegheny River near Pittsburgh.* (See Appendix R 9.)

* * * * * * *

REPORT.

APPENDIX R.

ANNUAL REPORT OF MAJOR WM. E. MERRILL, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1876.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, September 25, 1876.

GENERAL: I have the honor to transmit herewith annual reports on the works under my charge for the fiscal year ending June 30, 1876.

Very respectfully, your obedient servant,

WM. E. MERRILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

R 1.

IMPROVEMENT OF THE OHIO RIVER.

At the beginning of the fiscal year the following contracts were outstanding:

Number.	Miles below Pittsburgh.	Work.	Contractor.
1	760	Extension of French Island Dike	C. M. Cole.
2	782	Dike at Evansville	J. S. Routh.
3	797	Dike at Henderson Island	J. S. Routh.
4	797	Dam at Henderson Island	J. S. Routh.
5	....	Machinery of iron snag-boat	A. Hartupee.
6	....	Joiner-work and painting of iron snag-boat	W. F. Richardson.

FRENCH ISLAND DIKE, 760 MILES BELOW PITTSBURGH.

In my last annual report I stated that it had been found necessary to extend this dike to a much greater length than had been originally contemplated, and that I considered this work as an experiment of great value in determining how far the Ohio might be radically improved by guiding its currents. I accordingly contracted for an additional length of 1,518 feet to this dike, making its total length 3,498 feet. To make this extension, including some minor repairs on the old part of the dike, required an expenditure of 506 piles, 8,214 cords of brush, and 6,668 cubic yards of stone.

As this work was done during the season of low water it was followed by an immediate improvement in the channel-depth, this being so much increased that the bar ceased to be an obstruction. Whether this good result will be permanent I am unable to predict, as the river has been at a good boating-stage ever since the low water of last fall, during which the work was done. The only sure test is to ascertain the depth on the bar during the low water of the present season. Up to the present time the river has continued high.

EVANSVILLE DIKE, 783 MILES BELOW PITTSBURGH.

On account of high water during last season, a great flood having unexpectedly occurred in August, work on this dike was limited to keeping it up to grade, and to protecting the shore-end, below which appeared a dangerous scour. In this work there were expended 2,445 cubic yards of stone. The following is the report of Mr. Charles B. Bateman, the local engineer:

> Very little work was done on this dike last season on account of rise of river. The total length is 1,525 feet, of which about 200 feet at the outer end is 2½ feet below grade. The rest of the dike is up to grade, viz, 6 feet above low water, and in good condition. A very serious scour, immediately below the root of the dike, was discovered in the early part of June last, which endangered the work. A large amount of riprap was deposited at that point, which apparently has had the desired effect of arresting the scour.
>
> The effect thus far of this work has been to entirely wash away the sand from the bar opposite the city and to scour a channel across the bar which, from soundings taken lately, will give a depth of from 1.5 to 2 feet at low water. What is left of the bar is soft, impure clay. A channel yet remains to the left of the bar which somewhat neutralizes the effect of the dike on the bar itself. An addition of 500 feet contemplated this season to the length of the dike will close this left-hand channel, and throw the whole force of the current across the bar.

The extension of 500 feet, ordered last season, will be made during the present working season.

HENDERSON DIKE, 797 MILES BELOW PITTSBURGH.

This dike was extended 400 feet during the past season, making its total length 1,900 feet. The old part of the dike was brought up to grade, (6 feet above low water,) and the damages caused by the ice of January, 1875, were repaired. The work was finished in November, 1875, and the dike is considered as completed. During the year there were expended 187 piles, 2,963 cords of brush, and 3,260 cubic yards of stone. The dike seems to answer its purpose, as since its completion there has at no time been less than 4 feet on Henderson Bar; but this result, like that at French Island, cannot be depended on as permanent until it has been tested by the effect during the low water of the present year. The latest report for this locality indicates a lack of depth on the bar at the foot of the island. This bar is below the Henderson Bar proper, and did not exist when the Henderson dike was originally built. Its removal will probably necessitate the construction of another dike, commencing at a point on the Indiana shore, about 4,000 feet below the present dike. This is probably a better plan than any further extension of the existing dike.

In my annual report for 1874, I discussed the causes that had produced a deposit of gravel below the Henderson dike in places where there had been deep water for some months after the dike was built. This gravel evidently came from above, and must, therefore, have found some way to get over the dike. In that report I expressed the opinion that the phenomenon in question was due either to the formation of a ramp on the up-stream side of the dike in high water, up which gravel could be rolled by the current, or to transportation while frozen in and sustained by masses of ice. Neither of these explanations, however, appeared altogether satisfactory, and accordingly I made arrangements to have careful soundings taken above and below this dike in both high and low water. They were made by Mr. Bateman, in November, 1874, and in July and August, 1875. Careful platting and study show that during the August flood the bottom of the river was deepened both above and below the part of the dike nearest the bank. The maximum scour above the dike was 8 feet, and below it 19, both cases being near the shore-end. This scouring action diminished toward the middle of the river and beyond 900 feet from the shore, at which point the dike had curved considerably down stream; the reverse action was shown by a fill whose maximum height at a point 1,200 feet from the shore was 8 feet. From these facts I am compelled to conclude that this gravel was carried over the dike in suspension.

It is stated that on the Loire, after floods, enormous deposits of sand and gravel have been found at a height of from 5 to 10 feet above low-water line. As this gravel in many instances could not have been rolled to this height, it must have been carried there in suspension. A distinguished French engineer, M. Dupuit, gives an explanation of this apparent anomaly, which, in substance, is as follows: A solid substance rolling along the bed of a stream tends to acquire a velocity greater than that of the water, but it finds itself resisted by the liquid threads that surround it, and especially by those that have the slowest motion. It is therefore drawn toward the faster threads, which are those above it. If this tendency to rise is less than its weight in water, the body will descend until it reaches the bottom or a stratum of water where the two forces exactly balance. On the other hand, the body will rise if the upward pressure be greater than its weight. Lastly, if we suppose several similar bodies in suspension, their proximity to each other will tend to equalize the velocities of the threads that surround them, and therefore there will be less difference of velocity between the threads of water, and hence the bodies will remain suspended in a lower stratum than if they were isolated.

Running water can therefore hold in suspension bodies denser than itself. This power depends upon the differences in the velocities of the different strata of water; but the suspending power of any stratum is limited; that is, a cubic foot of water cannot hold in suspension more than a given quantity of material. Each stratum has, therefore, a different degree of saturation.

The observations at Henderson dike showed that the high-water current swept on a straight course, regardless of the dike, leaving a deposit in the low-water channel for whose improvement the dike was built. It is evident that the action of the dike, as long as it stands firm, will cut a channel through this deposit whenever the river falls low enough to bring it into play. This annual necessity for forcing a channel through high-water deposits seems unavoidable. The same state of affairs is found at the head of Cumberland Island, at which well-known locality it takes two or three weeks after a rise for the current to make the new channel, and during this time navigation suffers from shoal water.

HENDERSON DAM, 797 MILES BELOW PITTSBURGH.

This dam, whose object is to keep the water on the side of the island where the dike has been built, is finished. The damages caused by ice were thoroughly repaired and all weak points were strengthened. In this work were expended 84 piles, 1,508 cords of brush, and 1,047 cubic yards of stone.

The dam is 620 feet long and 50 feet wide at the middle, diminishing to 40 feet at the ends. In the middle it rises to 7 feet above low water, and at each end to 9 feet. Thus far it has fully accomplished the object of its construction.

IRON-HULL SNAG-BOAT.

This boat has been completed and is now actively at work. The record of her operations will be found further on. The cost of her machinery, including all extras, was $28,813.54, and the work was well done. Her cabin and joiner-work cost $8,000.

NEW CONTRACTS.

On the 12th of July, I opened bids for the removal of 17 wrecks from the Ohio, between Louisville and Cairo. The work was divided into two sections, the division being made at Slim Island, 9 wrecks being above this point and 8 below.

The following is an abstract of the proposals received for this work:

Number.	Bidders.	Above Slim Island.	Below Slim Island.
1	C. M. Cole	$5,500	$7,950
2	R. W. Dugan	5,500	6,000
3	Lowry & Higbee	6,500	6,200
4	M. S. Lord	7,325	5,325
5	Champion Coal and Towboat Company	8,445	8,995
6	Hill Wrecking Company	8,500	9,800

The contracts were awarded to C. M. Cole and M. S. Lord, the lowest bidders, for the two sections respectively, R. W. Dugan having retired in favor of C. M. Cole.

REMOVING OBSTRUCTIONS.

At the close of the fiscal year Mr. Cole, the contractor for the upper section, had done the following work:

Wreck of steamboat S. E. Hibbard, removed.
Flat-boat at Peckenpaugh Bar, all removed.
Bowlder-boat at Scuffletown Bar, partly removed.
Sunken ore-barge at Three-Mile Island, all removed.
Coal-boat at Diamond Island, partly removed.
Flat-boat at Slim Island, partly removed.

This contract has since been completed.

The contractor for the lower section, Mr. M. S. Lord, failed to furnish the necessary bonds, and hence his contract was declared forfeited. He did no work under it. This contract was not relet, as Mr. Lord's failure occurred quite late in the working season; and, besides, it was thought that the new snag-boat could remove these obstructions, rendering a contract unnecessary.

During the fiscal year the following snags were removed by special contracts:

Stump at Whitton's Tow-head.
Tree at Three Brothers Island.
Two snags at mouth of the Muskingum.
Fourteen snags between Marietta and Cincinnati.
Twenty-five snags between New Albany and Evansville.
One rack-heap near Abbot's Landing.

DREDGES.

The dredge-boats Ohio and Oswego are under orders to remove obstructions whenever they encounter them, as they move from point to point. In accordance with these orders they removed the following obstructions during the past fiscal year:

The Trap—Three coal-barges and a fuel-flat.
Crow Island—One coal-barge and three snags.
Raccoon Bar—One stone-boat and one snag.
Phillis Island—One coal-barge.
Steubenville Bridge—One coal-barge and one brick-boat.
Fishing Creek—One coal-barge and two snags.
Parkersburgh—Part of wreck of steamer Rebecca.

SNAG-BOAT E. A. WOODRUFF.

This boat was finished in January, but as snagging can only be done advantageously in low water, she did not go into commission until June. On the 8th of June she left Cincinnati for Pittsburgh, and at the close of the fiscal year (June 30) she had removed and destroyed 123 snags and 2 wrecks. One of the snags, thrown out by the Big Sandy, weighed 68 tons, and could hardly have been handled by anything less powerful than such a boat as the Woodruff.

As this boat is on her first trip, a description of her may be interesting. She has a wide, flat-bottomed hull, with broad stern and double-bow, being bifurcated for about two-fifths of her length. Her hull may be aptly described as being shaped like a boot-jack. Thirteen feet aft of her sterns a solid-built beam 8½ feet wide, with an average thickness of 18 inches, connects the two bows just above the water-surface. This is called the "butting-beam," because snags that are much imbedded are loosened by running the boat against them, catching the snags on this beam.

The principal dimensions of the boat are—

Extreme length, 177 feet.
Extreme width, 73 feet.
Length of hull, 175 feet.
Width of hull, 48 feet.
Four boilers, each 24 feet by 40 inches.
Main engines, 20 inches by 6 feet.
Hoisting engines, 9¼ inches by 14 inches.

She is also fitted with two steam-saws, one steam-auger, two steam-capstans, doctor, donkey-boiler, and a full supply of pumps. Her main hoisting-chain is of 1⅝-inch chrome steel, and is warranted to lift 72 tons.

The boat is a success in every respect, except in draught. No pains were spared to get this as small as possible, but notwithstanding all our care, the boat, though still the lightest double-bow snag-boat yet built, draws more than is desirable for service on the Ohio. She is now, when in complete order for work, down 11 inches by the stern, owing to the fact that the furnace and its fittings, which are near the stern, considerably overrun their estimated weights. When the boat is laid up for the winter, I expect to have her boilers moved forward sufficiently to get her on an even keel. Her draught, with boilers pumped up and 800 bushels of coal, will then be 34 inches. To lighten her to 30 inches, which is the draught that would best suit her work, would require a lengthening of about 31 feet, which would be both quite expensive, and would weaken the boat longitudinally. I believe that if the times for working in the upper river, where there is the greatest scarcity of water, are judiciously chosen, the boat will be able to do her full work without any hinderance. The only drawback is that the bars above Wheeling are of coarse gravel and bowlders, and are liable to injure boats that strike them. To compensate for this, this part of the river is almost entirely clear of snags, and but little time need be spent in it.

The snag-boat is now more actively engaged in clearing out obstructions, and is doing excellent service. The record of this work, however, belongs to the report for the ensuing fiscal year.

DREDGING.

The United States dredges Ohio and Oswego, in charge of Mr. E. J. Carpenter, assistant engineer, were continuously at work during the working season. The record for the fiscal year 1875–'76 shows a total excavation of 127,741 cubic yards, besides the removal of wrecks and snags, as reported above. The dredging was all done in the vicinity of Pittsburgh. In detail it is as follows:

Sawmill Run, Pittsburgh Harbor.—At the mouth of this run there was a heavy deposit extending into the channel, a large portion of which was due to the violent storm of July 26, 1874. The amount of excavation here was 19,201 cubic yards.

Brunot's Island, Pittsburgh Harbor.—Owing to low water the dredges could not descend the river after finishing at Sawmill Run. They were accordingly put to work at widening the entrance into the Glass-house Channel. This work was advantageous, though not strictly necessary. They removed 25,173 cubic yards.

Deadman's Island, 14 *miles below Pittsburgh.*—The work at this point consisted in the removal of a large isolated gravel bar, abreast of the head of the island, that interfered with the movements of coal-fleets. As much of the lump as was in the way of navigation was removed, the amount excavated being 22,807 cubic yards. The channel was widened 120 feet.

White's and Hays's Bar, 11 *miles below Pittsburgh.*—This is one of the worst places on the river. The work consisted in removing a lump in White's that lay next to the dike and just below the gap, (having, doubtless, been formed by material that had washed through the opening,) and in cutting off a portion of Hays's Bar that caused an objectionable cross-current. At White's the excavation amounted to 8,329 cubic yards, and at Hays's to 29,961 cubic yards. Nearly half of the latter excavation was done in May, when work was resumed for the present season. The removal of the little bar at White's added about 60 feet to the channel-width. The gap in the dike was cleared out and widened in order to give convenient access to the town of Middletown, on the left bank. This work occupied one of the dredges for 4 days. The work at Hays's was very severe on account of the hardness of the material. Since the close of the fiscal year it has been necessary to send the dredges back to Hays's Bar to level down some ridges which the current failed to flatten, as was expected.

Deadman's Island, 14 *miles below Pittsburgh.*—Work was resumed at this place in the spring, in order to cut off the point of the creek-bar which had recently obtruded into the channel, already objectionably crooked and narrow; 15,330 cubic yards of material were removed. This is the third time that I have had this creek-bar removed, while it has as often re-appeared under the influence of heavy rains. The original outlet of the creek was a mile and a half above, but about 9 years ago the neighboring farmers cut through the narrow bank between the creek and the river, giving the former a new outlet in a very objectionable locality. Since that time it has given us constant trouble.

Since the close of the fiscal year a low brush and stone dam has been built across the mouth of this creek, which will cause it to deposit its gravel and sediment in the eddy below the bar, and will therefore in all probability end the trouble at this place.

Raccoon Island, 273 *miles below Pittsburgh.*—At the end of June the dredges were at work at Raccoon Island, removing bars and straightening the channel. Up to the close of the fiscal year they had removed 6,940 cubic yards from this place.

TABULATED STATEMENT.

The following tabulated statement shows the work of the dredges and the expenditure on them for the calendar year 1875. It is believed that this statement is in better shape than that for 1874, which was given in my last annual report. It was considered unnecessary and deceptive to attempt to separate the work of the two dredges, as they always work together, and therefore they are treated as one in the tables.

UNITED STATES DREDGES OHIO AND OSWEGO.	In commission, 1875.	Time	Dredging		126.0 days.		
			Wrecking		4.0 days.		
			Lost	Traveling	11.5 days.		
				Accidents	12.0 days.		
				High and low water	19.5 days.		
				Sundays	29.0 days.		
			Total		202.0 days.		
		Work	Cubic yards excavated during season			142,092	
			Cubic yards excavated per working-day			1,093	
			Cubic yards excavated per day in commission			703	
			Wrecks removed			9	
			Snags removed			6	
		Cost	Equipment	For the season			$1,098 31
				Per working-day			8 45
				Per day in commission			5 48
			Towing	For the season			10,534 61
				Per working-day			81 83
				Per day in commission			52 15
			Salaries	For the season			9,383 00
				Per working-day			72 18
				Per day in commission			46 45
			Repairs	For the season			1,458 99
				Per working-day			11 22
				Per day in commission			7 22
			Total	For dredging			21,780 19
				For wrecking			694 72
				Per working-day			173 68
				Per day in commission			111 25
				Per cubic yard excavated			0 17
	Out of commission, 1875.	Time	In ordinary		129 days.		
			Annual spring repairs		34 days.		
			Total		163 days.		
		Cost	Total in ordinary				$551 11
			Per day in ordinary				4 27
			Spring repairs				1,703 83

Date, 1875.	Miles from Pittsburgh.	Place.	Kind of work.	Days at work.	Excavation.			Expenditures.		
					Number of cubic yards.	Cubic yards per day of work.	Cost per cubic yard.	Total for dredging, including expenses in ordinary and spring repairs.	Total for wrecking, including expenses in ordinary and spring repairs.	Grand total.
								126 days.	4 days.	
May and June	215.0	Buffington Island	Dredging	40	49,284	1,232.1	$0.154	$7,609 18		$7,609 18
July	183.5	Parkersburgh	Wrecking	1					$190 23	190 23
July, August, and September	1.5	Saw-Mill Run	Dredging	14	19,201	1,371.5	0.138	2,663 21		2,663 21
Do	2.0	Head of Brunot's Island	do	25	25,173	1,006.9	0.189	4,755 75		4,755 75
September	11.0	White's Ripple	Wrecking	2					380 46	380 46
September and October	14.0	Deadman's Island	Dredging	21	22,807	1,086.0	0.174	3,994 82		3,994 82
October and November	11.0	White's Ripple	do	10	8,329	832.9	0.228	1,902 30		1,902 30
Do	11.0	Hays's Bar	do	16	17,298	1,081.1	0.176	3,043 67		3,043 67
November	35.5	Phillis Island	Wrecking	1					190 23	190 23
Totals				130	142,092	1,093.0	0.174	23,968 93	760 92	24,729 85

EXPLANATORY NOTES.—It will be observed that the cost of the annual spring repairs has been separated from what may be called the running repairs due to breakages while at work.

The contract-price for towing was $50 per day, Sundays excepted, with no deductions except when the tow-boat was not ready for duty. Under the charter she was to furnish the dredges with coal without additional charge. Occasionally an extra tow-boat was hired for a few days. This expense is included under "towing."

It will be observed that the actual cost of dredging has been reduced to 17½ cents per cubic yard, which is a favorable showing where work is prosecuted under so many disadvantages as on the Ohio River.

SPECIAL SURVEYS.

During the year the following special surveys have been made:

Sites for 9 locks and dams between Pittsburgh and Wheeling, in order to obtain better locations than those selected during the preceding year. A check-line of levels was also run from Pittsburgh to Bellaire.

Dam behind Wheeling Island.

High-water observations at Cincinnati to determine the courses traveled by coal-tows in passing site of Cincinnati Southern Railroad bridge.

Peninsula opposite Evansville, to determine the danger of the river cutting through.

Observations on bed of river at Henderson Dike in high and low water.

OFFICE-WORK.

This has included work on a continuous map of the Ohio River, on the scale of 2 inches to the mile, the preparation of a general plan of the proposed lock at Davis Island, drawings and tracings of special surveys, platting water-gauge records, completion of detailed drawings and tracings of machinery of snag-boat, and drawings of an iron crane for the dredge Oswego.

MOVABLE DAM AT DAVIS ISLAND.

The appropriation bill for the year 1875-'76 contained the following item:

> For the improvement of the Ohio River, $300,000; that $100,000 of this amount shall be used for and applied toward the construction of a movable dam, or a dam with adjustable gates, for the purpose of testing substantially the best method of improving permanently the navigation of the Ohio River and its tributaries; the location of the work, with the plan of construction and the application of the amount hereby appropriated, to be submitted to the Secretary of War for his approval.

In my last annual report I gave a brief history of my efforts to procure from the State of Pennsylvania the legislation necessary to enable me to commence the construction of the movable dam authorized by Congress. In accordance with the instructions of the Chief of Engineers, I now give this history in detail.

The necessity for having recourse to a State legislature for additional legislation before commencing a Government structure comes from section 355 of the Revised Statutes, which reads as follows:

> No public money shall be expended upon any site or land purchased by the United States for the purposes of erecting thereon any armory, arsenal, fort, fortification, navy-yard, custom-house, light-house, or other public building of any kind whatever, until the written opinion of the Attorney-General shall be had in favor of the validity of the title, nor until the consent of the legislature of the State in which the land or site may be to such purchase has been given. * * *

Anticipating the improvement of the Ohio by permanent structures of some kind, and being desirous to have all legal obstacles out of the way before work should begin, I consulted with General Moorhead, of Pittsburgh, chairman of the board of Ohio River commissioners, and between us a bill was prepared for cession of jurisdiction by the State of Pennsylvania, which bill passed both houses of the Pennsylvania legislature, but was vetoed by the governor. The following is the text of the bill and of the veto:

AN ACT to grant the consent of the State of Pennsylvania to the acquisition by the United States of certain lands within the State, and bordering on the Ohio River, for the purpose of erecting thereon dams, abutments, locks, lock-houses, offices, and other necessary structures for the construction and maintenance of slack-water navigation on the said river, and ceding jurisdiction over the same.

SECTION 1. *Be it enacted by the senate and house of representatives of the Commonwealth of Pennsylvania in general assembly met, and it is hereby enacted by the authority of the* *same*, That whenever the United States shall begin the radical improvement of the Ohio River by means of locks and movable dams, the consent of the State of Pennsylvania, through the governor thereof, is hereby given to the acquisition by the United States, by purchase or by condemnation, in the same manner as land is now taken for public purposes under any general or special statute for railroad or other purposes, (and should the property which the Government desire to acquire have been dedicated to a religious or charitable use, the proceeds of such property shall be invested and used to and for the same use and purpose to which the property taken was originally dedicated or conveyed,) of such pieces of land, not to exceed two acres in any one piece, bordering on the Ohio River, as may be necessary for the purpose of erecting thereon dams, abutments, locks, lock-houses, offices, and other necessary structures for the construction and maintenance of slack-water navigation on said river, and the said United States shall have, hold, use, occupy, and own the said land or lands when purchased, and exercise jurisdiction and control over the same and every part thereof, subject to the restrictions hereinafter mentioned.

Sec. 2. In case the United States shall decide to resort to condemnation in acquiring land for the purposes specified in the first section of this act, the said United States shall in all respects be governed by the laws regulating the appropriation of private property for public use, and said laws are hereby made applicable: *Provided*, That the United States may pay the costs and refuse to take the land, if in their judgment the compensation assessed therefor is excessive.

Sec. 3. The jurisdiction of the State of Pennsylvania in and over the said land or lands, when purchased by the United States, shall be, and the same is, hereby ceded to the United States, but the jurisdiction hereby ceded shall continue no longer than the said United States shall own the said land or lands.

Sec. 4. The said consent is given, and the said jurisdiction ceded, upon the express condition that the State of Pennsylvania shall retain concurrent jurisdiction with the United States in and over the land or lands, so far as that all civil process, in all cases, and such criminal or other process as may issue under the laws or authority of the State of Pennsylvania against any person or persons charged with crimes or misdemeanors committed within said State, including said lands, may be executed therein in the same way and manner as if such consent had not been given or jurisdiction ceded, except so far as such process may affect the real or personal property of the United States.

Sec. 5. The jurisdiction hereby ceded shall not vest until the United States shall have acquired the title to said land or lands, as herein provided; and so long as the said land or lands shall remain the property of the United States, when acquired as aforesaid, and no longer, the same shall be and continue exonerated from all taxes, assessments, and other charges which may be levied under the authority of this State.

Sec. 6. That any malicious, willful, reckless, or voluntary injury to, or mutilation of, the grounds, buildings, or appurtenances, shall subject the offender or offenders to a fine of not less than twenty dollars, to which may be added, for an aggravated offense, imprisonment not exceeding six months in the county jail or work-house, to be prosecuted before any court of competent jurisdiction.

Sec. 7. This act shall take effect immediately.

H. H. McCormick,
Speaker of the House of Representatives.
B. B. Strong,
Speaker of the Senate.

VETO.

Executive Chamber,
Harrisburg, May 29, 1874.

I herewith file in the office of the secretary of the commonwealth, with my objections thereto, house bill No. 252, entitled "An act to grant the consent of the State of Pennsylvania to the acquisition by the United States of certain lands within the State, and bordering on the Ohio River, for the purpose of erecting thereon dams, abutments, locks, lock-houses, offices, and other necessary structures for the construction and maintenance of slackwater navigation on the said river and seding jurisdiction over the same."

This bill is unconstitutional. Section 1 authorizes the "condemnation, in the same manner as land is now taken for public purposes under any general or special statute for railroad or other purposes," which is in conflict with section 6, article 3, of the constitution.

Section 6 of the bill imposes fines and penalties not mentioned in the title nor germane thereto.

J. F. Hartranft.

Section 6, article 3, of the constitution of the State of Pennsylvania, to which the governor refers, reads as follows:

> No law shall be revived, amended, or the provisions thereof extended or conferred by reference to its title only, but so much thereof as is revived, amended, extended, or conferred shall be re-enacted and published at length.

During the session of 1874–'75 a new bill was introduced, which was carefully prepared so as to meet the governor's objections. This bill read as follows:

AN ACT to grant the consent of the State of Pennsylvania to the acquisition by the United States o certain lands within the State, and bordering on the Ohio River, for the purpose of erecting thereon dams, abutments, locks, lock-houses, offices, and the necessary structures for the construction and maintenance of slackwater navigation on the said river, and ceding jurisdiction over the same, and for imposing fines and penalties for willful injuries to the grounds, buildings, and appurtenances acquired under the provisions of this act.

SECTION 1. *Be it enacted by the senate and house of representatives of the commonwealth of Pennsylvania in general assembly met, and it is hereby enacted by the authority of the same,* That whenever the United States shall begin the improvement of the Ohio River by means of locks, movable dams, and adjustable chutes, the consent of the State of Pennsylvania, through the governor thereof, is hereby given to the acquisition by the United States, by the purchase, or by condemnation in the manner hereinafter provided, of any lands, buildings, or other property necessary, for the purpose of erecting thereon dams, abutments, locks, lock-houses, chutes, and other necessary structures for the construction and maintenance of slackwater navigation on said river, and the said United States shall have, hold, use, and occupy the said land or lands, buildings, and other property when purchased or acquired as provided by this act, and shall exercise jurisdiction and control over the same.

SEC. 2. If the United States shall determine to take lands, buildings, or other property necessary for the purposes mentioned in the first section of this act, and cannot agree with the owner or owners of such lands, buildings, or other property for the compensation to be made for such taking, the court of common pleas having jurisdiction in the county where such lands, buildings, or other property are situated shall, upon application by either the United States or the owner or owners, or any one in behalf of either, appoint three disinterested freeholders to ascertain and determine the amount of compensation to be paid to such owner or owners, who shall make report to the said court of their award on or before the first day of the term next after their appointment: *Provided,* That the said United States shall not be authorized to take possession of, or use or occupy, the lands, buildings, or other property taken under the provisions of this section until the amount of said award shall be paid to the owner or owners thereof: *Provided further,* That the said court may set aside the report of said viewers, upon being satisfied that the amount of said award is excessive.

SEC. 3. That if any person or persons shall willfully or maliciously injure any of the lands, buildings, or other property acquired or held under the provisions of this act, such person or persons shall be liable to a fine of not less than twenty dollars, and to an imprisonment not exceeding six months, or both or either, at the discretion of the court, said offense to be prosecuted and punished in any court of competent jurisdiction.

This bill passed the house, but was mislaid in the senate, and, thus losing its turn, could not be again called up before adjournment.

A third effort was made in the fall of 1875, the bill of 1874 being re-introduced without change, except to include the Monongahela River, so as to provide for the anticipated new lock and dam on this river at Laurel Run, in the State of Pennsylvania. I regret to state that this bill was defeated by the efforts of the coal-shippers of Pittsburgh, who have during the year just passed developed considerable opposition to the radical improvement of the Ohio.

I am, therefore, compelled to report that, owing to inability to secure from the State of Pennsylvania the necessary cession of jurisdiction, no work has yet been done toward the construction of the first movable dam on the Ohio River, and therefore the allotment of $100,000 was not used. It is proper to add that the prices charged by the riparian owners for the land needed for the lock were so much in excess of the actual value of the property. that it seemed a duty to wait until authority could be obtained to condemn the land by legal process. Such authority was included in the bill introduced into the Pennsylvania legislature.

The opposition of the coal-shippers, which has manifested itself since my last annual report, seems to have arisen chiefly from their objection to the payment of tolls. They assume that the running expenses of the locks and dams will be met by tolls on passing water-craft, and they decidedly object to such an enforced contribution. I have endeavored to show them that the tolls would be very light, and that the advantage of being able to keep their steamboats and barges in constant use would more than compensate them; but thus far they have refused to be persuaded. The truth is, that if the Ohio River were provided with a perpetual 6-foot navigation, there would be no need for the huge fleets that can only run during a few months in the year, and at other times are tied to the bank. The traffic in coal would become regular and constant. We should no longer hear of coal-gluts or coal-famines, of fortunes made or lost. A steady stream of coal would flow down the river every day in the year, and the shipment of coal would cease to be a speculative business; the small dealer could enter the business with safety, and competition would keep the price low.

The advantage to consumers would be incalculable. At present there is not a large manufacturing establishment on or near the Ohio and Mississippi Rivers that is not compelled to keep on hand at all times a large stock of coal for which it has no immediate use, but which it must retain for fear of low water and a consequent coal-famine, although it is well known that coal rapidly deteriorates when exposed to the weather. The advantage of being able to buy by the barge-load coal fresh from the mine, in quantity as needed, would be worth millions to the industry of the Ohio Valley.

For these reasons I cannot but think that the course of the coal-dealers of Pittsburgh is unjustifiable and contrary to public policy. They condemn the whole project in advance, and refuse to consent to the construction of even one dam, notwithstanding the great local advantages to be gained by it, and notwithstanding the fact that, in case of failure, the dam could be removed without either injury or delay to navigation.

I am far from desiring to do anything that will injure the coal-trade, and my record will show that I have worked faithfully to improve the river, and especially its upper portion, so that coal-tows might run with more ease and safety; but I recognize the fact that the shipment of coal is not the only nor even the chief commerce on the Ohio River, that, however valuable in its effect on other industries, the total annual value of the coal that descends the Ohio is but about $6,000,000, as compared with a general river-commerce of about $200,000,000.

Under these circumstances I think that the objection of the Pittsburgh coal-shippers should be overruled, and that the construction of the Davis Island dam should be kept steadily in view; and that every proper effort should be made to secure the requisite authority from the State of Pennsylvania.

Since my last annual report my assistant, Lieut. F. A. Mahan, Corps of Engineers, has spent 3 months in Europe, chiefly in France, devoting his time to a study of engineering works, and especially of movable dams. He has kindly prepared the following brief summary of the results of his observations, which I think merits preservation in the Annual Report of the Chief of Engineers. It is proper to state that Lieutenant Mahan visited France on a leave of absence and at his own expense, and that his report is a voluntary one:

CINCINNATI, OHIO, *July* 25, 1876.

MAJOR: In accordance with your request, I have the honor to present the following items that I collected while abroad this past spring, and which I think may be of some use in studying the application of movable dams to the Ohio River.

The French movable dam to which I gave the greatest attention was naturally the one at Port à l'Anglais, as this is the one proposed as our model for the Ohio River. I visited this dam for the first time on the 13th of April.

The season of my being abroad was in some respects unfortunate, because I arrived in France just at the time when the Seine was at the highest it had been for years, having overflowed its banks for a great distance above Paris, and in many places the water-line was 3 or 4 feet above the bank. The river began to fall very shortly afterward, and by the end of April it was almost down to its normal low-water state.

At the time of my first visit to the dam the river was still very high, there being only 6 wickets of the old pass standing, and 1 trestle of the new pass. M. Boulé showed me the manner of raising and lowering a trestle of the new pass. He then showed me the full-size models of three kinds of wickets used in this dam. These models stand on the right bank of the river, about 15 yards from the abutment of the new pass. It is necessary to see these models to obtain an idea of the size of the wickets. Although I had made the drawings for the small model in the office, I never realized how large these wickets are until I saw them. After examining these we crossed over to the lock.

It may be well to give here a brief description of the lock and dam.

The Port à l'Anglais dam is situated on the Seine, about 2½ miles above Paris.

The lock is on the left bank of the river; it is 688 feet; 95 long from out to out. Its breadth is 39.37 feet, and its available length, 580.37 feet.

The dam is divided into three parts, standing in the following order as we pass from the lock to the opposite shore: First, the old pass; second, the weir; third, the new pass. The old pass is 179.46 feet wide; the weir, 115.16 feet; and the new pass, 94.16 feet. The size of the wickets of the old pass is 9.84 feet high by 3.94 feet wide; those of the weir are 6.56 feet high by 4.25 feet wide; and those of the new pass 13.02 feet high by 3.28 feet wide. The wickets of the old pass are maneuvered by means of a boat, but the weir and the new pass have a movable bridge.

After having crossed the river, we first examined the lock, which presented no very special features of interest. From the lock we entered the maneuvering boat of the old pass, and about a dozen of the wickets were drawn into place. After this we went ashore, and I was shown the arrangement of the lock-keeper's house, the telegraphic apparatus, &c.

On the 25th of April the operations for closing the dam were begun, and lasted through this day and the 26th.

The operation of raising the trestles is very simple. A long hook, somewhat similar to a boat-hook, is used, to which is fastened one end of a rope, of which the other end is attached to the drum of a small windlass. The hook is taken by a man in a row-boat, and he casts it forward so as to catch hold of the trestle to be raised. After finding that the hook has caught the trestle, the men at the windlass start it and draw the trestle up. When nearly vertical, one of the men at the windlass catches it with a wooden bar that has a shoulder at each end. One of these shoulders is engaged on the top of the trestle just raised, and the other on the top of the trestle preceding. One of the planks of the service-bridge is now run forward, and then the iron joining-bars (barres de réunion) [eye-bars] are set in place. The windlass is now carried forward, so as to be ready for the next trestle.

In casting for a trestle it frequently happens that the hook does not obtain a firm hold. In this case, so soon as the trestle is raised above the water and the defective hold is noticed, a line is made fast to it and to the trestle last raised, until a new hold can be taken with the hook.

The trestles of the weir are raised in a similar way, but the operation is much more simple, as they are much lighter.

After all the trestles of the pass have been raised and the planks forming the floor of the service-bridge have been laid, the wickets are drawn up with a larger windlass used for this purpose, and left swung until after the wickets of the old pass are raised.

The operation of raising the wickets of the old pass is the one that requires the greatest skill, as it is no easy matter to catch a handle of less than a foot in length with an ordinary hook, when the wicket is lying some 5 or 6 feet under water, with a swift current flowing over it that becomes more and more swift as each wicket is raised. For this work 5 men are required, and, in addition to the ordinary maneuvering-boat, a second boat or skiff is needed. The maneuvering-boat has the principal windlass near the stern and another smaller one at the bow. The use of this latter will be explained further on. The men, whom for convenience I shall designate as Nos. 1, 2, 3, 4, and 5, are stationed as follows when work begins: No. 1 at the bow, with the grappling-hook, to which is attached the line leading to the windlass; No. 2 stands near No. 1; Nos. 3 and 4 are at the windlass, on the port and starboard sides respectively; No. 5 is by himself in the skiff on the down-stream side of the dam. Every one being in place, No. 1 engages the hook in the handle of the wicket; No. 2 immediately hauls in the slack of the line, and holds it until the strain has fully come upon the windlass; Nos. 1 and

2 then go to the assistance of Nos. 3 and 4. When the wicket is hauled up, No. 5 feels with his boat-hook to see if the prop be in place, and, if he so find it, then the wicket is allowed to assume its upright position. When the wicket has taken its place, No. 1 catches its top with a boat-hook, to which the line of the second windlass is attached. The top is drawn forward by No. 2, and No. 5 then works the prop around a little to see that it is properly seated against the heurter. While Nos. 1, 2, and 5 are thus engaged, No. 4 unrolls from the windlass enough line for the next cast, but, as this process imparts considerable velocity to the drum, No. 3 stands by to check it with a brake. All this being done, Nos. 3 and 4 cast loose the chains that hold the maneuvering-boat, these chains being of such a length as to allow the boat's head to occupy its exact position, and Nos. 1, 3, and 4 push her forward to her next station, 3 and 4 make fast the chains, and the operation proceeds as before.

In all this work the exact point at which the hook takes hold is a matter of no importance either for the trestles or the wickets. The rule is to catch whatever you can that will hold. The handle is of course the only thing on the wicket that will give a hold; but I have seen the trestles caught by an upright, a cross-piece, a brace, and in two or three cases merely by a bracket-plate. From what I saw here I became convinced that there would be no use in attempting to handle wickets of the size of those in the new pass by means of a maneuvering-boat, and when I spoke about it to M. Boulé, the engineer in charge of Port à l'Anglais dam, he said that it would be impossible, and further that it would be almost a folly to build a Chanoine dam of that size without a bridge, because it would be very soon found that the bridge was not only a very great convenience, but an absolute necessity. M. de Lagrené was of the same opinion. On the other hand M. Remise, at Auxerre, said that he would not feel the slightest hesitation in attempting to handle these large wickets with a maneuvering-boat, and the lock-tender at Ile Brulée said the same thing; but then he was accustomed to a wicket of 9.84 feet height, and between this and 13.02 feet there is a great difference. But suppose that wickets of this size could be handled readily by means of a boat, how are we to manage about beginning work on the rest of the dam after the main part is closed? The head of water formed by closing the pass will cause such a current through the rest of the dam that it will be very hard to begin work, and once begun, as we advance, it will soon be found an impossibility to catch the wicket, as the current will become so strong as to prevent the man who has the hook from exercising any control over it. At the Port à l'Anglais dam, while closing the old pass, both the new pass and the weir were left open; but by the time the last two or three wickets were reached it became a very delicate operation to seize the handle of the wicket, requiring not only great dexterity, but also great strength to prevent the current from carrying the hook away, although the fall was not more than 2½ feet. If this be the case at this difference of level what would it be at 5½ or 6 feet?

Again, if we attempt to maneuver the whole dam by means of a boat, we shall find that before the dam is closed, the water in the pool will have risen so high that the guards of the boat will no longer rest against the wickets, but will be above them. From this cause we shall find two difficulties that will stop our work. The boat not having her accustomed support will be too unsteady to work from in casting for the wickets; and then, again, not being held out in her true position by means of her guards, the line of direction of the force applied to raise the wicket will be so nearly vertical that it is doubtful whether the wicket will come sufficiently far forward to allow the prop to fall into its seat against the heurter. Another trouble will be the risk of having the boat carried over the dam, because her draught is less than 9 inches, and at the time of closing the dam we shall probably have that amount of water flowing over the comb of the dam.

The above difficulties are the ones we shall find in maneuvering the pass if we take it last.

Suppose, now, that we take the weir last. Then, in addition to the difficulties above mentioned, we shall have another arising from the position of the axis of rotation. This axis being placed very low, in order to make the wicket more sensitive, we run a great risk of causing it to tip over when the guards of the boat rest against the top, owing to the dynamic pressure of the water transmitted through the boat to the head of the wickets. Another objection to the exclusive use of a maneuvering boat is that it does not furnish us with adequate means for keeping the surface of the pool at a fixed height. This necessity is usually met by limiting the swing of the weir-wickets by regulating chains, but all the experiments that have thus far been tried for confining the wickets have proved to be more or less unsuccessful unless "a point of attachment be provided for the chain which is easily accessible in all weathers, and even at night, whatever be the height of the water. We must be able to change the length of the chains, and consequently the inclination of the wickets in all weathers and even at night, so as to regulate at will the surface of the pool. The service-bridge * * * seems to be the only mode of completely solving the problem." * * * * (Report of the Chief of Engineers, 1875, Part 1, pp. 725, 726.)

From what I have said above, I consider it absolutely essential that both the pass and the high weir should be provided with a bridge. This seems to me to be only reasonable, and it is in accordance with the opinions of the greater number of the French engineers with whom I conversed on the subject.

The drift of opinion seemed to be in favor of the Poirée system for closing weirs wherever the depth of water on the weir is not greater than 6 or 6¼ feet. The needles can be very easily handled by one man, and they afford a very simple mode of regulating the height of the pool, as it is only necessary to take out as many as may be needed to give sufficient opening for the flow of the water. The needles, when taken up, are laid on the down-stream side of the floor of the bridge, where they can easily be found when the pool falls sufficiently to have them replaced. A good deal of skill is required in handling the needles, but no great amount of strength, the whole secret being in causing the water to do the greater part of the work. The Poirée system, however, is not suitable for the pass. The difficulty of handling such large needles as are required in passes is very great. At the Suresnes dam the needles are 13.02 feet in length, with a cross-section of 4 inches by 4 inches. They weigh, when dry, 44 pounds, and when wet from 66 pounds to 70.4 pounds. When it becomes necessary to remove some of them in order to increase the discharge, it is impossible for the dam-tender to work them by hand. He is provided with a little jack, by means of which he forces out the head of the needle, and then holds it out with a couple of blocks of wood placed between it and the needle on either side. If the needles are to be taken from the water, it has to be done in the following very clumsy way:

A boat is moored about 30 or 40 yards above the dam. In this boat is a windlass worked by two men. One end of a line is attached to the windlass and the rest of it coiled upon the foot-bridge, where a third man is stationed. The latter takes a double half-hitch on whichever needle he wants removed; the men in the boat turn the windlass, and thus the needle is hauled into the boat and then taken ashore.

M. de Lagrené, to whom I spoke very particularly of the difficulties of the Ohio River, including the peculiar method of coal-towing, advised me that it would be well to have one dam built just below Pittsburgh, and then wait for two or three years to see how it will work and how it will answer the demands of the river trade. He said, furthermore, that, owing to the great length that we would have to give to the various parts, it would also be well to wait for that length of time, because our experience might then suggest modifications that would be useful in those to be built afterward.

Very respectfully, your obedient servant,

F. A. Mahan,
First Lieutenant, Engineers.

Major William E. Merrill,
Corps of Engineers, U. S. A.

In view of the above report, which is the result of a careful personal inspection of existing French movable dams, made with the express intention of procuring all available knowledge of their actual working, and in view of the additional fact that this knowledge was sought and acquired by an officer thoroughly familiar with the Ohio River and its commerce, with the special view of adapting it to the solution of the problem of radically improving the Ohio River, I have the honor to recommend the following change in the project previously presented, namely, the introduction of a service-bridge for use in maneuvering the Chanoine wickets. The only reason why this was omitted in my former project was that I was desirous of saving the cost of its construction. I am now satisfied that we cannot get along without it.

My estimate on the cost of movable dams was based on the supposition of the use of Chanoine wickets on the pass and on both weirs, but I expressly stated that I intended to leave the question open for the present as to the kind of apparatus to be used on the high weir, and that I assumed Chanoine wickets merely to obtain an estimate of cost. I am now satisfied, after a thorough discussion with Lieutenant Mahan, that experience abroad indicates the Poirée needle-dam as the best apparatus for the high weir. These changes necessarily call for a new estimate of cost, and therefore I submit the following as the estimate of the cost of the first movable dam on the Ohio, which has been located at Davis Island, 5 miles below Pittsburgh. The prices of labor and material having changed since my first estimate was made, present prices have been used. In view of his recent experience abroad, the preparation of this revised estimate was assigned to Lieutenant Mahan.

MOVABLE DAM AT DAVIS ISLAND.

This dam will be provided with a lock 679 feet long between gates, and 78 feet wide, a navigable pass 400 feet wide, a low weir 400 feet wide, and a high weir 400 feet wide. The navigable pass and the low weir will be closed by Chanoine wickets, with service bridge above, and the high weir by a Poirée needle-dam. The lock and navigable pass will be on rock and the remainder of the dam on gravel.

Lock.—The estimate for the lock will be the same as that given in Report of the Chief of Engineers for 1875, part 2, page 616 *et seq.*, which is $179,610.

Pumping.—The cost of pumping for the whole dam will be taken at the figures given in the report just quoted, or $3 per running foot of dam.

Navigable pass coffer-dam, per running foot.

Material.	Price.	Quantity.	Cost.
String-pieces	$15 per 1,000	85 feet	$1 28
Sheeting-planks	...do	150 feet	2 25
One-inch round iron ties	3 cents per pound	53 pounds	1 59
Gravel	50 cts. per cub. yard	6 yards	3 00
Labor			5 00
Total cost			13 12

Foundation of pass, per running foot.

Material.	Price.	Quantity.	Cost.
Rock-excavation	$2 per cubic yard	4.5 cubic yards	$9 00
Cut-stone masonry	$15 per cubic yard	3.72 cubic yards	55 80
Rubble masonry	$6.50 per cubic yard	13.22 cubic yards	8 59
Sills, (lumber)	$25 per 1,000	34 feet	85
Labor			10 00
Total			84 24

Appurtenances of the sole, per wicket and trestle, and per running foot.

Name.	No.	Material.	Quantity.	Price.	Cost.	Cost per foot.
Trestle.						
Anchoring-rod	1	Wrought iron	75 pounds	6 cents per pound	$4 50	
Anchoring-disk	1	Cast iron	80 pounds	3½ cents per pound	2 80	
Journal-boxes	2	....do	110 pounds	......do	3 85	
Labor					5 00	
Total for trestle					16 15	$4 59
Wicket.						
Anchoring-rod	1	Wrought iron	75 pounds	6 cents per pound	4 50	
Anchoring-disk	1	Cast iron	80 pounds	3½ cents per pound	2 80	
Journal-boxes of horse	2	....do	110 pounds	......do	3 85	
Heurter and slide	1	Wrought iron	480 pounds	6 cents per pound	28 80	
Tripping-rod	1	....do	98 pounds	......do	5 88	
Guides	2	....do	42 pounds	......do	2 52	
Roller	1	Bronze	26 pounds	40 cents per pound	10 40	
Labor					5 00	
Total for wicket					63 75	18 11
Total for trestle and wicket.					79 90	22 70

Superstructure, per trestle and wicket, and per running foot.

Name.	No.	Material.	Quantity.	Price.	Cost.	Cost per foot.
Trestle.						
Trestle	1	Wrought iron	1,350 pounds.	8 cents per pound	$108 00	......
Joining-bars	2	...do	117 pounds	......do	9 36	......
Chains	2	....do	200 pounds	......do	16 00	......
Bridge	....	Plank, (pine)	20 feet	$11 per 1,000	22	......
Labor	....				5 00	......
Total for trestle	....				138 58	$39 37
Wicket.						
Horse	1	Wrought iron	450 pounds	6 cents per pound	27 00	......
Prop	1	....do	600 pounds	......do	36 00	......
Journal-boxes of wicket	2	Cast iron	110 pounds	3½ cents per pound	3 85	......
Bolts and nuts	30	Wrought iron	330 pounds	3 cents per pound	9 90	......
Panel	1	Timber, (oak)		$40	40 00	......
Labor	....				5 00	......
Total for wicket	....				121 75	34 59
Total for trestle and wicket.	....				260 33	73 96

Low-weir coffer-dam, per running foot.

Material.	Price.	Quantity.	Cost.	Cost per foot.
String-pieces	$15 per M	85 feet	$1 28	....
Sheeting-plank	$15 per M	150 feet	2 25	....
One-inch round iron ties	3 cents per lb	53 lbs	1 59	....
Gravel	50 cts. per cu. yd	6 cu. yds	3 00	....
Labor			5 00	....
			13 12	$13 12

Foundation, per running foot.

Material.	Price.	Quantity.	Cost.	Cost per foot.
Concrete	$5 per cu. yd	3.62 cu. yds	$18 10	....
Rubble masonry	$6.50 per cu. yd	4.83 cu. yds	31 40	....
Cut-stone masonry	$15 per cu. yd	1.70 cu. yds	25 50	....
Sheeting of concrete frame	$15 per M	40 feet	60	....
Uprights of concrete frame	$15 per M	105 feet	1 58	....
Gravel	50 cts. per cu. yd	1.36 cu. yds	68	....
Riprap	$1.60 per cu. yd	1.22 cu. yds	1 95	....
Sills	$25 per M	34 feet	85	....
Labor			5 00	....
			85 65	$85 65

Appurtenances of the sole per running foot, $18.85; superstructure, $61.65; on the basis of five sixths of the cost of similar parts of the pass.

High-weir coffer-dam, per running foot.

Material.	Price.	Quantity.	Cost.	Cost per foot.
String-pieces	$15 per M	85 feet	$1 28	....
Sheeting-planks	....do	150 feet	2 25	....
One-inch round iron ties	3c. per lb	53 lbs	1 59	....
Gravel	50c. per cu. yd	6 cu. yds	3 00	....
Labor			5 00	....
Total			13 12	$13 12

Foundation, per running foot.

Material.	Price.	Quantity.	Cost.	Cost per foot.
Concrete	$5 per cu. yd	1.25 cu. yds	$6 25	
Gravel	50 cts. per cu. yd	2 cu. yds	1 00	
Cut-stone masonry	$15 per cu. yd	1 cu. yds	15 00	
Sills	$25 per M	34 feet	85	
Riprap	$1.60 per cu. yd	3 cu. yds	4 80	
Labor			5 00	
Total			32 80	$32 80

Appurtenances of the sole, per running foot.

Number.	Name.	Material.	Quantity.	Price.	Cost.	Cost per foot.
1	Anchoring-rod	Wrought iron	75 lbs	6c. per lb	$4 50	
1	Anchoring-disk	Cast iron	80 lbs	3½c. per lb	2 80	
2	Journal-boxes	do	80 lbs	3½c. per lb	2 80	
	Labor				5 00	
	Total				15 10	$4 29

Superstructure, per running foot.

Number.	Name.	Material.	Quantity.	Price.	Cost.	Cost per foot.
1	Trestle	Wrought iron	500 lbs	8c. per lb	$40 00	
2	Joining-bars	do	50 lbs	8c. per lb	4 00	
16	Needles	Timber, (oak)	120 feet	$25 per M	3 00	
	Foot-bridge	Plank, (pine)	16 feet	$11 per M	18	
	Labor				5 00	
	Total				51 18	$14 54

Piers.

Foundation for pier, 11.48 feet wide	$854 00
195.53 cubic yards of cut-stone, at $15	2,932 95
172.65 cubic yards of rubble, at $6.50	1,122 23
Capstan for tripping rod	1,000 00
Total for 1 pier	5,909 18
Total for 2 piers	11,818 36

Abutment—foundation for abutment.

Material.	Price.	Quantity.	Cost.
Piles, ten feet long, driven	$4.20 apiece	12 piles	$50 40
Sheeting piles, ten feet long, driven	$3.70 apiece	125 piles	462 50
Concrete	$5 per cu. yd	30 cu. yds	150 00
Total			662 90

Superstructure and accessory works.

Material.	Price.	Quantity.	Cost.
Cut-stone masonry	$15 per cubic yard	103.5 cubic yards	$1,552 50
Concrete backing	$5 per cubic yard	87.17 cubic yards	430 85
Capstan and gearing		1 capstan and gearing	1,000 00
Grading bank, paving, &c			5,000 00
Total			7,983 35

SUMMARY.

Navigable pass.

Coffer-dam, per running foot	$13 12
Pumping, per running foot	3 00
Foundation, per running foot	84 24
Appurtenances of sole, per running foot	22 70
Trestle, per running foot	39 37
Wicket, per running foot	34 59
Total, per running foot	197 02
Cost for 400 feet of width	$78,808 00

Lowweir.

Coffer-dam, per running foot	$13 12
Pumping, per running foot	3 00
Foundation, per running foot	85 65
Appurtenances of sole, per running foot	18 8
Wicket and trestle, per running foot	61 65
Total, per running foot	182 27
Cost for 400 feet of width	$73,108 00

High weir.

Coffer-dam, per running foot	$13 12
Pumping, per running foot	3 00
Foundation, per running foot	32 80
Appurtenances of sole per running foot	4 29
Trestle	14 54
Total	67 75
Cost for 400 feet of width	$27,100 00

Abutment.

Foundation	$662 90
Superstructure	7,983 35
Total	8,646 25

Gathering together these detached estimates, we have:

Navigable pass	$78,808 00
Low weir	73,108 00
High weir	27,100 00
Two piers	11,818 36
Abutment	8,646 25
Engineering and superintendence two years, at $6,000	12,000 00
Total	211,480 61
Contingencies, 20 per cent	42,296 12
Total estimated cost of dam	253,776 73

Dam behind Davis Island.

Cost of dam per running foot:

One row of sheet-piling, 10 feet, at $4.75 per running foot, driven	$4 75
40 feet, board-measure, caps, at $15	60
28 feet, board-measure, stringers, a t$15	42
53½ feet, board-measure, ties, at $15	80
3 piles driven, at $5	15 00
3.7 cubic yards stone-paving, at $3.50	12 95
12.0 cubic yards riprap, at $2	24 00

2 cubic yards gravel, at 40 cents	$0 80
Labor	5 00
Total per running foot	64 32
Cost for dam 420 feet long	$27,014 40
Contingencies, 10 per cent	2,701 44
Total	29,715 84

The total estimated cost of the first movable dam on the Ohio is, therefore:

Lock	$179,610
Movable dam	253,777
Dam behind Davis Island	29,716
Total	463,103

which may be put in round numbers at $465,000.

It should be borne in mind that the prices assumed are the existing prices for labor and material, both of which are low, and may be higher before actual construction is begun. It must also be stated that all work in the bed of a river as liable to floods as the Ohio is subject to contingencies, in the way of stoppages and damages to unfinished work, that cannot be foreseen. I have endeavored to provide for them under the head of contingencies, but it is quite possible that my allowance is too small. If one movable dam had been built, it would be possible to estimate on another with more exactness. Under the circumstances the above estimate is the best that can now be made.

CUMBERLAND DAM.

The dam at the head of Cumberland Island, just above the junction of the Cumberland River with the Ohio, has been a serious cause of trouble during the present low-water season. It has often given trouble before, but not to so great a degree.

The following statement of the injury to navigation caused by the condition of affairs at this place has been compiled from the river-columns of the Cincinnati Commercial:

June 15, 1876.—Thompson Dean detained three days, boat drawing 8 feet; 6 feet only on the dam.

August 5.—Idlewild had trouble in getting over the dam.

August 6.—Shannon lost 2 days' time and was compelled to discharge part of cargo in order to get over.

August 8.—Depth reported in Cumberland Chute 3.5 feet. Depth over the dam 4.4 feet.

August 7–9.—Arkansas Belle lodged one day on the dam and afterwards grounded in the chute and was compelled to get barges from Paducah and lighten off. Arrangements made with steamer Jim Fisk to meet Evansville packets here and reship Cairo freight. Channel in chute reported very narrow and ragged.

August 14.—Tow-boat James Gilmore was compelled to leave part of her tow above the dam.

August 21.—Idlewild aground 12 hours. James Gilmore compelled to lie up above dam.

August 23.—Fontenelle detained 40 hours above dam.

August 28.—Thos. Sherlock rubbed in going over the dam.

September 4.—Thos. W. Means laid up, not able to get over.

September 11.—Idlewild rubbed hard.

September 13.—J. W. Silverthorn rubbed hard.

September 14.—Arkansas Belle detained.

September 15.—Cherokee rubbed hard, broke chain of a model barge she had in tow. Arkansas Belle detained.

September 17.—Thos. Sherlock lost one day. Blue Wing detained. Robin rubbed hard. Cons. Millar detained.

September 18.—Arkansas Belle detained.

In addition to the above I have had several urgent requests from Captain Grammer, superintendent of the Evansville and Cairo Packet Company, to do something to relieve the difficulties experienced by boats at this place.

The repair of this dam was evidently ordered on the strength of my report of February 14, 1872, (printed as Ex. Doc. No. 165, H. of R., 42d Cong., 2d session, and reprinted in Report of Chief of Engineers for 1872, pp. 409, 412.) This report gives a full history of this dam, and to it I would respectfully refer for additional information. The dam was begun in 1832, and partly finished, repaired, and completed in 1838, partly repaired in 1854, and thoroughly repaired and completed in 1872–'74. Since 1874 it has rarely been out of water, but a recent letter from the former inspector of the work of reconstruction informs me that there has been some subsidence in the new part of the dam, connecting the old dam with the head of Cumberland Island, but that the main dam stands firm.

In recommending the repair of the Cumberland dam, I naturally assumed that the only question involved was that of the permanence of the work, and that if we could make the dam stand, the results which were originally sought, and which seemed from old reports to have been attained as long as the dam was in good condition, would re-appear. Feeling confident that the dam could be made reasonably permanent, and believing this to be the only question involved, I therefore recommended its repair. Experience shows that the dam has been made sufficiently durable, but that the result is unfavorable from an unforeseen cause. The difficulty is due to the fact that at high water, when the dam is so deeply submerged as not to affect the current, the main volume of the river crosses the dam, while the Kentucky Chute is in comparatively still water, and receives heavy deposits of sedimentary matter. As the river falls the influence of the dam begins and gradually increases, and its ultimate effect is to force a strong current through the Kentucky Chute, washing out the deposits of high water and creating a navigable channel. If the river falls very slowly this channel can be washed out in time to prevent any injury to navigation, but if the fall is sudden, or if the Cumberland is in a flood and backs up the Ohio, there is not time enough to do this scouring work, and for a period of uncertain length there is no channel either over the dam or through the chute. This, I think, explains fully the present difficulty at Cumberland dam.

The original object of building this dam, as stated by Captain Delafield in 1833, was—

> To throw the low-water channel to the left of the island and by the town of Smithland to avoid a shoal bar near the lower point of the island.

As stated in 1854 by Mr. Charles A. Fuller, United States agent and engineer, was to—

> Open an uninterrupted low-water communication with the Cumberland River via the Kentucky Chute.

The first reason appears altogether insufficient for undertaking so great a work. At all events the dam utterly failed to secure the result indicated, as there has always been a bad bar at the foot of Cumberland Island.

The reason alleged by Mr. Fuller appears to me to be the only correct one. But since Mr. Fuller's time the river-business has greatly changed and the commerce of the Cumberland has become insignificant. The practical effect of Cumberland dam at present is merely to compel all low-water navigation on the Ohio to pass the semi-defunct town of

Smithland, for which they pay an annual tax in detentions at the dam, and in the loss of freight on account of occasional inability to carry as much water over or around the dam as can be carried over the other ruling bars.

Under these circumstances I think that the Cumberland dam has survived its usefulness, and should be removed. This can easily be done during the low water by the United States dredge-boats, and the material can be advantageously used in improving the channel at the foot of the island and in keeping open the natural mouth of the Cumberland River.

The only interest that will be injured will be that of the town of Smithland, as, during low water, steamboats will not find it so convenient to stop there. It seems to me that this should not weigh against the interests of the general commerce of the Ohio. As matters stand now I do not feel at liberty to remove the dam in the face of an order of Congress to rebuild it, but I trust that the foregoing statement will be sufficient to justify its removal during the next fiscal year.

The appropriation for the improvement of the Ohio River during the fiscal year 1876–'77 was $175,000. The Secretary of War has ordered that the expenditure during the fiscal year be limited to $120,000.

Estimate for 1877–'78.

For snag-boat, dredges, and office	$100,000
For riprap, dams, and dikes	185,000
For completion of movable dam at Davis's Island, ($100,000 already appropriated)	365,000
	650,000

Since the date of my last annual report I have found in the March number of the *Annales des Ponts et Chaussées* of the current year a description of a very valuable modification of the Port à l'Anglais dam, made by M. Boulé, the engineer in charge. A joint translation of the article referred to has been made by Lieutenant Mahan and myself, and it is herewith presented (accompanied by one plate) as a supplement to this report This article brings up to date the record of movable dams as built in France.

Money statement.

Amount available July 1, 1875	$274,611 40
Amount expended during fiscal year ending June 30, 1876	157,590 45
Amount available July 1, 1876, including $8,688.16, due on contracts, &c.	117,020 95
Amount appropriated by act approved August 14, 1876	175,000 00
Amount that can profitably be expended in fiscal year ending June 30, 1878.	650,000 00

R 2.

PLAN AND LOCATION OF MOVABLE DAMS FOR THE OHIO RIVER.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., May 4, 1875.

SIR: In order to carry into effect so much of the river and harbor act of March 3, 1875, as appropriates $100,000 toward the construction of a movable dam, or dam with adjustable gates, for the purpose of testing the best mode of improving permanently the navigation of the Ohio River and its tributaries, the location of the work, with the plan of construction and the application of the amount appropriated, to be approved by the Secretary of War, I have the honor to submit for your consideration a report from a Board of engineer officers convened to examine and report upon the plan and location of the work in question, as proposed by Major Merrill, Corps of Engineers, in charge of the Ohio River improvement. It will be perceived that this Board approves the plan and location suggested by Major Merrill, and recommends that the work be constructed accordingly.

The report of the Board is concurred in by me.

Very respectfully, your obedient servant,

A. A. HUMPHREYS,
Brigadier-General and Chief of Engineers.

Hon. W. W. BELKNAP,
Secretary of War.

[Indorsement.]

Approved.
By order of the Secretary of War.

H. T. CROSBY,
Chief Clerk.

WAR DEPARTMENT, *May* 5, 1875.

REPORT OF THE BOARD OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, April 19, 1875.

GENERAL: The Board of engineer officers appointed by Special Orders No. 42, dated Headquarters Corps of Engineers, Washington, D. C., April 6, 1875, have the honor to report that they met at Pittsburgh, Pa., on the 14th instant.

In accordance with the instructions of the 7th instant, from your office to its presiding officer, the Board gave the subject referred to in that letter, and on which they were required to report, as full consideration as was practicable.

A number of drawings from the office of Major Merrill relating to it were examined and studied; conferences with persons residing in Pittsburgh who were interested in it were invited and held with leading gentlemen representing this class, and the site of the proposed dam was visited.

The Board then adjourned to Cincinnati, and at Major Merrill's office additional drawings relating to the subject, and a model of the movable portion of the proposed dam, were examined and studied.

The stage of water in the river was so high that it was impossible to examine closely the site proposed for the dam, but from the soundings and surveys which have been made, there seems to be no doubt that it will furnish a satisfactory foundation for the structure, the lock portion of which will be on rock. If, however, the Chief of Engineers should deem it necessary to do so, the Board can be reconvened when the river shall have fallen to its lowest stage, and further examinations of the site for the remainder of the dam can then be made, but this should in no wise interfere with beginning the lock, as it will cause no change whatever therein.

With regard to the plan of the proposed dam, which has been submitted by Major Merrill, the Board are of the opinion that it is satisfactory. It is similar to the plans that have proved successful after long experience under like conditions in France, and it is modified by improvements suggested by that experience.

The site chosen for the dam is necessarily regulated by the fall of the river, which fortunately brings it in a position where there is an excellent foundation for that portion which includes the lock, and where the river-bank above and below for a considerable distance is straight and abrupt, and thus will afford easy ingress and egress.

The dimensions and details for the lock have been carefully matured, and are considered by the Board to be judicious.

A portion of the remainder of the dam will be founded on the same rock strata whereon the lock will be situated. The other part of the dam, nearest Davis Island, will rest upon a bed of sand and gravel upon which a secure foundation can be constructed without difficulty and at no unreasonable expense.

The Board therefore recommend that the site chosen for the dam, and the plans submitted for it by Major Merrill, be adopted, and that he be authorized to proceed at once with the construction of its lock, which is essential and necessarily the portion that should be first constructed.

Of the gentlemen with whom we conferred, three are members of the Ohio River Improvement Commission, one of them being the president, and the second the chairman of the executive committee of that commission. They express confidence in the success of the plan which we recommend.

We will now describe how the proper site for the dam was determined, and then discuss the details of the lock, the pass, and the weirs.

The chief consideration in choosing a site for the first movable dam on the Ohio, is to so locate it that the raising of the water-surface by the dam shall at all times give a minimum depth in the harbor of Pittsburgh of 6 feet. As the depth in river-harbors is necessarily dependent somewhat upon the condition of the sedimentary deposits in the bed of the river, it is necessary to refer to a well-established water-gauge for the normal level of the artificial pool to be created by the dam. We have selected as the proper standard for this purpose the gauge in the Monongahela River, a little above the foot of Market street.

This gauge was established to show the depth of water on the Glass-house Shoal, about 2 miles below. It does this as accurately as is possible in a river like the Ohio, whose bars usually vary somewhat in height according to the stage of water and its duration.

As the improvement of the depth of water throughout the harbor of Pittsburgh should be the controlling consideration in determining the position of the first dam, we have therefore concluded that the latter should be so placed that the top of the dam will be at the same absolute level as the 6-foot mark on the Monongahela gauge. This will therefore secure at least 6 feet throughout the Monongahela harbor of Pittsburgh during the smallest discharge of the Ohio, and will usually secure a foot or two more, which will be a decided advantage.

The proper location for this dam is therefore determined by the profile. The details of the dam will be discussed further on, but it is proper to state here that the plans submitted propose to raise the water 10 feet higher than the low-water line at the site of the dam.

The following levels show the heights above mean ocean-tide of various points on the Ohio River. The altitude assumed for the zero of the Pittsburgh gauge is that given by Mr. J. T. Gardner in his pamphlet just published under the authority of the Secretary of the Interior.

Zero of the Pittsburgh gauge is 699.20 feet above mean-tide.

Low water at—	Miles below Pittsburgh.	Height above mean tide.
		Feet.
Head of Brunot's Island	2	698.882
Superior Rolling Mill	3.5	695.986
Wood's Run	4	695.140
Bellevue Station	6.5	695.050
Head of Neville Island	7	692.117

By adding 6 feet to the altitude of the zero of the gauge we obtain 705.20, which is the level to which the water should be raised. Subtracting 10 feet from this we obtain 695.20 as the altitude of the low-water line at the place where the dam must be put. We find that this would place the dam at Wood's Run, which is an unfavorable site. But the fall between Wood's Run and Bellevue Station (opposite Davis Island) is only .09 foot and the foundations at the latter place are all that could be desired. We therefore think that the proper location for the first dam on the Ohio is at or near Bellevue Station.

The site for the dam having been found, we will now discuss its details.

It will consist of a lock, a navigable pass, a low weir, and a high weir.

After a careful consideration of the plans proposed by Major Merrill, aided by the practical experience of a trip of several miles on a coal-fleet, we fully approve of the width and length of lock recommended by him, believing that a smaller lock would not meet the legitimate requirements of the navigation peculiar to the Ohio River. The lock proposed has a width of 78 feet and an available length of 630 feet.

For closing the navigable pass, the Board find that but two systems have thus far been adopted in France, the Chanoine and the Poirée, both of which are fully explained in Ex. Doc. No. 78, 43d Congress, second session.

Considering the great width of river to be closed, and the limited number of attendants that should be kept at each dam, the Board are of opinion that it is better to use the Chanoine wickets for the navigable pass. For the two weirs they do not recommend any system absolutely, but they would suggest that this matter be left for future consideration, with a view to using on the high weir some system that can be operated by the fall which will necessarily be generated by raising the other portions of the dam. It is also possible that the Poirée system may be advantageously used on the low weir.

As both the lock and the navigable pass must be constructed before either of the weirs is begun, the Board think it best to leave the matter of the crowning of the weirs to be discussed at some future time. No question of practicability is involved in temporarily postponing this subject, as it is certain that the whole dam may be made and worked on the Chanoine plan, but it is believed that it would be for the interest of the Government not to decide this question absolutely until the time is at hand for actual construction, Additional study and experiment in this country and abroad may result in a still better solution of this part of the problem.

Respectfully submitted.

H. G. WRIGHT,
Lieut. Col. of Engineers, Bvt. Maj. Genl.
G. WEITZEL,
Major of Engineers, Bvt. Maj. Genl. U. S. A.
O. M. POE,
Major of Engineers, Bvt. Brig. Genl. U. S. A.
WM. E. MERRILL,
Major of Engineers and Bvt. Colonel.

F. A. MAHAN,
1st *Lieutenant Engineers, Recorder.*
Brig. Genl. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

R 3.

SUPPLEMENT.

MOVABLE DAMS WITH HIGH LIFTS.

Memoir by M. Boulé, Engineer of Ponts et Chaussées, on a new system of movable dams closed by gates and trestles.

INTRODUCTION.

Some of the engineers who have visited the dam at Port à l'Anglais since the construction of the navigable pass, an account of which was given in an article published in the *Annales* in August, 1873, have made various objections to the mode of closing adopted for this pass, or have expressed doubts upon the opinions that I advanced in the article on the subject of the utility and possibility of establishing on other rivers dams of the same kind having a height of more than 13.12 feet and a lift of more than 9.84 feet.

While acknowledging that the solution adopted at Port à l'Anglais was the only one that up to that time had been approved by experience for so high a lift, they expressed the opinion that it would be well to seek a more simple and more economical mode of closing, especially if a pool still higher than that at Port à l'Anglais had to be formed.

It seemed to me useful and interesting to discuss the observations that have been made to me on this subject, and to re-examine the advantages and disadvantages of the different systems of movable dams now in use, and this discussion made me think of a new solution of the question, which appeared to me the most simple and economical of all.

I was thus led to propose a new style of dam, which will, I think, allow very deep pools to be formed without too great expense, and will, at the same time, present great advantages, while avoiding all the serious disadvantages alleged against the other systems.

This discussion and this proposition formed the subject of an article that I sent on the 1st of August, 1874, to the commission of the *Annales*, but the commission did not think that it ought to authorize its publication, "for the reason that the traditions of the *Annales* do not allow inventors to set forth in the collection new ideas that have not been experimented on." The trial of the new system of dam was decided on by a ministerial order of November 24, 1874, approving a plan for gates to be established against the trestles of the Port à l'Anglais dam, which would allow, says this order, "trials to be made on a new form of dam, which may lead to the solution of the ever-pending question of dams with high lifts."

This plan was carried out, and the pool, maintained by the wickets of the Chanoine system in the new Port à l'Anglais Pass, was temporarily kept up by the trestles of the service-bridge through the medium of gates of the new model.

The experiment with these gates was several times made in the presence of a number of inspectors-general and engineers of the *Ponts et Chaussées*, and it appeared to be sufficiently conclusive for this mode of closing to be adopted, by a ministerial order of the 14th of last July, for the dam at Port Villez, of which the construction, begun several years before on the Lower Seine, was to be continued on the new system.

Furthermore, I was requested by a ministerial dispatch of June 5, 1875, "to resubmit to the commission of the *Annales* my article on movable dams, after having completed it by the report of the experiments to which it gave rise."

The present article is the reply to that invitation. It is divided into two parts: the first includes the general description of the new dam, gives the reasons for the proposed arrangements, and shows their advantages; the second gives the dispositions adopted and the experiments made at Port à l'Anglais.

CHAPTER I.

GENERAL DESCRIPTION OF THE DAM, WITH TRESTLES AND GATES, AND THE REASONS FOR THE PROPOSED ARRANGEMENTS.

1. *Substitution of ordinary gates for needles in the dams of M. Poirée.*

The dam, with trestles and ordinary gates, may be described in a few words. It is composed of the simplest and earliest known parts: the trestles of M. Poirée and the ordinary gates of hydraulic works. The gates slide vertically between two consecutive trestles, as those of mills move between two masonry abutments, and sometimes even between two wooden posts. They are maneuvered in the same way, with a jack-screw from on top of the foot-bridge supported by the trestles.

Among the parts entering into the construction of the different movable dams, the trestles of M. Poirée undoubtedly present the greatest number of advantages and the fewest disadvantages. At the same time that they support the gates they form a service-bridge that is always very useful, even when it is not indispensable, no matter what the kind of dam, and the presence of this bridge allows all machinery to be placed above the level of the pool, and no fragile part that may require repairing need be placed under water.

The needles of M. Poirée's dams have, on the contrary, many well-known disadvantages. It is they alone that thus far have limited the height of trestle dams. Their use requires the construction of a long and costly permanent weir alongside of the movable dam. Finally, the curtain of needles is not sufficiently water-tight. It is to avoid these disadvantages that efforts have been made to close dams by means of turning-gates, of various forms, but these are not themselves free from faults, and it is somewhat remarkable that we have always been obliged to employ trestles for remedying them.

Just as M. Chanoine, in 1850, established a foot-bridge carried on trestles, at Courbeton, in order to maneuver the shutters of M. Thénard's system, so similar bridges have been built since then, in order to maneuver the wickets of M. Chanoine, not only for the weirs, but also for the passes, when the height of these latter is great.

But we are thus led to a very costly and somewhat complicated system, in which the trestles and supports of the wickets appear to do the same thing twice, for we must give the trestles the same dimensions and the same solidity as if they were to support the pool by themselves.

Trestles do not even seem to be useless at the dams of M. Desfontaines in spite of their small height, very little more than 3.28 feet, as is shown in the note published by M. Malézieux, December 29, 1874, (*Annales*, May, 1875,) in which he again describes the coffer-dam with movable trestles at the Joinville dam, which he had briefly noticed in his article on this dam,.(*Annales*, 1868, 2d half-year.)

These considerations have led me to think that the solution for movable dams, a solution that is always pending, according to the ministerial decision of November 24, 1874, above quoted, would be found by resting-gates similar to the wickets of M. M. Thénard, Chanoine, and others, or more simply ordinary sliding-gates directly against the trestles of M. Poirée, and by suppressing the special supports for the wickets, their axes of rotation, their tripping rods, and other accessories.

But ordinary mill-gates remain constantly in place against their supports when they are raised above the water, and each of them has a rack and its own particular maneuvering screw.

In a trestle dam the gates must be carried to the store-house as fast as they are taken up, as is now done with the needles; hence we should only have to use one lifting-machine for all the gates, instead of having one for each, and the surface of each gate should be so small as to make it easy to carry it along the surface-bridge to the store-house on the bank.

It is evidently easy to design a windlass or a crane that can raise or lower all the gates in succession and which can move backward and forward on the bridge formed by the trestles, as is now done by the windlass used in maneuvering the wickets of the weirs of the Upper Seine and those of the navigable passes of the Marne, of the Saône, and of the new Port-à-l'Anglais Pass. Each gate in succession will be attached to this hoisting apparatus, either by means of a chain constantly fastened to each one, or by a maneuvering pole, which will be engaged in the handle of the gate from the top of the service bridge, just as the handles of the wickets of M. Chanoine's system are seized from the maneuvering boat when we desire to raise them. .

In all dams where trestles are used, either to hold up the pool through the agency of needles or only to form a service-bridge, the distance between the trestles is somewhat small, and never varies much from 3.28 feet. In fact, the pressure supported by the trestles is proportional to their distance apart, and if this distance be too great, we must make their transverse dimensions too great; and they consequently become too heavy, as would be the case also with the joining bars, which unite them together and form also the rails on which the maneuvering windlass runs. As a general rule, it is even well to bring the trestles nearer together as their height increases.

Hence the breadth of the gates to be placed between two consecutive trestles will not be very great; but if these gates were of the same height as the trestles, this height would make them unwieldy so soon as the depth of the pool became considerable; and when we wanted to raise one it would extend to a considerable distance above the foot-bridge, and therefore we should have trouble in guiding it and in transporting it on the foot-bridge.

We will, therefore, place in the interval between two trestles several gates, one above the other, their heights being equal to, or a little greater, than their breadths. This arrangement is the key of the system, and makes all the maneuvers easy.

2. *Maneuvering the gates—Numerous facilities and advantages that they present.*

The system of gates resting against trestles will thus be composed of several horizontal rows of rectangular gates, just as dams made of beams are formed of a certain number of joists superposed horizontally. We must insist on this arrangement, because it is the essential part of the system.

To open the dam we shall proceed as with beams, by first taking away the top row of gates, then the next row, and so on.

At the instant of raising, each gate will support the head of a column of water of which the height is equal to the depth of flow over the top, increased by the height of the gate itself, if the latter be entirely clear of the lower pool. In the contrary case, the head will be the total lift of the dam; but this lift will then be very small.

When the upper row of gates, which are evidently lightly loaded, have been removed throughout the entire length of the dam, the level of the upper pool will fall, or, if it be kept up by an increased discharge of the river, the level of the lower pool will rise, and in any case the fall at the dam will diminish rapidly. The second row of gates will consequently be raised under almost the same circumstances as the first, and this will continue until we reach the lowest row resting on the sill. The lowest gates, completely immersed in the lower pool, will be even more easily raised than those above; because when they are lifted the fall will have almost disappeared.

Hence all the maneuvers will be easy, and will never require very strenuous efforts if the length of the dam be great enough to prevent too deep an overflow and if the surface of the gates be not too great. When the dam is to be closed, the reverse order will be observed; all the gates in the lowest row will be first let down, while the fall is still little or nothing; then those of the next row will be placed, in order to stop the flow over the first row, and so on. Hence it appears that it ought to be easier to close the dam than to open it, because the work will then be done under smaller heads.

Furthermore, the maneuver of opening or closing will never be done all at once, but successively and progressively, as the discharge of the river varies; hence we have no need to trouble ourselves about the duration of the maneuvers.

The number of gates placed against the trestles will be daily increased or diminished, just as in the Poirée dams a certain number of needles is put down or removed successively, making greater or smaller openings, so that the water-way of the dam shall always correspond to the discharge of the river. The level of the upper pool, instead of undergoing a sudden change at any maneuver, will remain, so to speak, invariable, except when the river rises above the normal level of the pool after all the gates have been removed. Then only will it be necessary to let down the trestles, to raise them again when the natural height of the water shall have fallen below the normal level of the pool. We can then begin at once to close the dam, without ever allowing the water to fall below the normal level of the pool.

Dams closed by wickets turning about an axis of rotation, present, on the contrary, a great disadvantage when viewed from this standpoint, because we must wait, after a flood, for a considerable fall in the pool before we can raise the wickets and close the dam. Furthermore, it will rarely be necessary to open the dam entirely and let down the trestles, and this maneuver will be the less frequent as the height of the dam becomes greater.

The complete opening of the movable dams does not take place more than two or three times a year on the Upper and Lower Seine, and sometimes it is still less frequent; thus the dams between Paris and Montereau, closed in May, 1873, were not opened until December, 1874, after having remained closed for more than eighteen months consecutively.

M. Chanoine's dams must be opened entirely when the discharge of the river becomes so great as to cause the wickets of the pass to swing spontaneously, and the same necessity is presented in M. Poirée's system when the level of the lower pool threatens to reach the service-bridge. The height of the trestles of a dam with gates, not being limited, as in M. Poirée's system, by the necessity of reducing the length of the needles as much as possible, the foot-bridge can be raised considerably higher than the surface of the pool and can even be placed above ordinary floods.

This result is very important, and allows us to be easy as to the length of the maneuvers, for we no longer have to fear being unable to finish opening the dam before the arrival of a flood, and seeing it submerged without being able to complete the maneuver, as twice happened at Suresnes during the floods in the beginning of 1873. In fact, this dam was first submerged from January 21 to February 11, 1873, with all its trestles standing and 250 needles in place, and also from the 27th of February to the 28th of March with 90 needles in place. Something similar happened at the Evry dam during the flood of 1866, as all the wickets of the weir remained swung on their horses during the entire flood, because there are no tripping-rods on the weirs of the Upper Seine, and in 1866 the trestle-bridges had not yet been constructed.

These two accidents had no disastrous consequences, but they might have had, and it is certainly very well to avoid their recurrence, as can be done with the dam of gates and trestles, if the level of the foot-bridge is sufficiently raised.

The ease with which the water-way can be varied to suit the requirements of floods is also very important.

The maneuvering of the dams of M. Chanoine is already too rapid, and the engineers of the Upper Seine are constantly instructing the dam-tenders to do it very slowly; for when a dam is opened too rapidly an artificial torrential flood is caused that is often very dangerous, and when the dam is closed too rapidly the supply of the lower pool is disproportionately reduced, and boats are liable to ground.

Quick maneuvers might be useful in forming artificial floods with low dams, but they cannot be permitted with high dams, especially where a number of dams are built in regular succession, because their effects are cumulative, since it becomes necessary, as a rule, to open or close them almost simultaneously. The most quiet river thus becomes a torrent when all the dams are maneuvered together, and navigation is very much embarrassed, both at the general opening and the general closing of the dams.

From this point of view, the gate-dam will present the same advantages as the needle-dam; besides, the discharge, taking place by overflow throughout the entire length of the river, will be equally divided over this extent; scours will be less feared, and injurious eddies will not be caused below the locks, as is sometimes the case on the Upper Seine when the weir is partly opened and the pass is closed.

Finally, we shall be able to obtain the same result as if, in a stationary dam, we could gradually lower the crest as the discharge increases.

Hence, we shall thus realize the dam with movable sill, lately demanded by the general council of the *Ponts et Chaussées* in order to avoid placing the permanent sill above the bottom of the river, as M. Saint-Yves has mentioned in an article published in November, 1870, in the *Annales*, page 440.

The lowest row of gates will be taken up but very rarely; they might be raised a little sometimes to prevent deposits on the up-stream side.

In chapters VI and VII of the article on the dam at Port-à-l'Anglais, I insisted upon the utility of arranging movable dams in such a way that they can vary their water-ways in all proportions, according to the discharge of the river, and that all their operations may be carried on under the smallest possible head. I showed that these results can be obtained, no matter what the system of closing may be, by dividing the dam into several sections, of which the sills are set at different levels; but this solution is costly, because it causes a very great length to be given to the dam.

In a dam composed of several ranks of ordinary gates sliding vertically between trestles, the same results will be obtained in another way, that is probably more simple and more economical. It will always be desirable, in order to reduce expenses, to limit the breadth of the deep navigable pass to the dimensions strictly necessary for navigation; but here, however, the cost of first construction will not increase so rapidly with the height as in more complex systems. On the other hand, as the navigable pass will be closed by several ranks of gates, it might really form the entire dam by itself, and in case of necessity we could find in it, one below the other, the various passes at different heights, which must be placed alongside of each other in a dam formed of gates or needles, of a height equal to that of the pool. This might be useful in a dam established in a narrow part of the river, as in a city where the river is inclosed between quay walls; for example, if it had been desired to complete the Monnaie dam at Paris by closing the right arm, as had formerly been contemplated, or if we wished to build a dam at the mouth of the Saône at Lyons, as they are now proposing, in order to raise the water-surface in the passage through the city, and on the mitre sill of the Ile Barbe lock. In every case we should examine in different lights, and especially in that of cost, whether it be better to diminish the total length of the dam by increasing that of the deepest pass, or to adopt the contrary solution, while still preserving the same discharge-area for floods.

For this we shall have a facility not offered by other systems, and we shall have at the same time another solution to the problem which M. Charles Poirée only solved in the Monnaie dam at the expense of navigation, because boats cannot pass this dam. There will always be over the gates of the new dam, as over the section of La Monnaie, an overflow of variable depth according to the discharge of the river and the total length of the dam, but sufficient to keep in the upper pool a surface current, and to carry off the drift that always accumulates above needle dams. I need not add that this overflow will permit us, as in wicket-dams, to dispense with the permanent wier; which, however, is indispensable with needle-dams, in order that the pool may not rise to the level of the service-bridge.

We know that doing away with the permanent weir is a great economy, which alone compensates for the heavy costs of constructing dams that permit an overflow, like those of M. Chanoine and M. Desfontaines. The overflow which is only intermittent in the dams of M. Chanoine on account of the spaces between the wickets, will in our case be perpetual, as at La Monnaie, because the gates will be almost entirely tight if constructed with care, and then the entire discharge of the river will flow over the crest of the gates as over a weir.

This property of the dam will allow almost the entire volume of the river to be used for water-power, and the value of the force thus utilized will be equal, if the fall is moderately great, to the cost of constructing the dam, a cost that will thus become productive, independently of the improvement of navigation.

In spite of the inevitable loss of water, it is probable that we shall be able to measure at any instant the discharge of the river over the weir of thin plates formed by the gates, with an approximation at least equal to that which can only be obtained by long and complicated operations, and, consequently, only at rare intervals, by means of surface floats, of the Woltman mill, or the Pitot-Darcy tube. We shall then be able to indicate with great exactness to the lock-tenders of the lower dams the maneuvers that they should execute under all circumstances, according to the change in the discharge of the river. This is not the case with dams of needles or of Chanoine wickets, and lock-tenders are sometimes liable to act hastily and thus cause troublesome consequences below.

Finally, the gates having to be raised and stored during floods, like the needle-dams of M. Poirée, it will always be easy to keep them in good order, to repair, calk, and pitch them. This is not the case with the dams of M. Chanoine and others, whose wickets are always under water, be the dam closed or open. Moreover, the keeping in order of these wickets is difficult and very onerous.

3. *Dimensions and arrangements of the gates.*

The breadth of the gates will be determined by the space between the trestles. It will never be much greater than 3.28 feet, and it will generally diminish as the height of the pool increases. As to their height, it will depend at the same time on the depth required for the pool, on the width of the service-bridge, over which they have to be carried, and on the solidity of this bridge, which alone limits the power of the hoisting-apparatus. The service-bridge being necessarily more solid as the trestles are stronger and nearer together, while at the same time the pool increases in depth, we shall be able to increase the height of the gates in high dams, so as to diminish the number required. In particular, we shall be able to allow a considerable height to the gates, which rest at the bottom on the sill of the dam, and are always covered by the lower pool, because they will never be maneuvered except when the head is nearly destroyed, or, at least, is very small.

However, as the total surface and the weight of the gates must never be too great to be manageable, I think that this surface ought, as a rule, to be from 10 to 20 square feet, and that it should not vary much from 15 square feet.

The gates of the upper ranks will habitually be maneuvered under a head slightly greater than those at the bottom, and it may, perhaps, be advantageous to make them not quite so high; finally, it will be very advantageous to place at the top a row of very light gates, which the dam-tenders can handle by hand without the assistance of a windlass. If the gates of the top row be only from 0.83 foot to 1 foot high, they will be reduced to simple light boards, because, being always under a small pressure, they may be very thin. They can be handled as easily as small needles, and yet by taking them up the discharge will be increased 2 or 3 cubic feet per running foot, which will generally suffice to regulate the height of the pool during the entire season of low water. Should the river be subject to greater variations of discharge, or should the length of the water-way of the dam be small, we might place at the upper part two ranks of gates of this kind. They would be very much like stop-planks, with the difference that instead of regular beams, they would merely be short planks.

If these little gates at the top be but 1 foot high by 4 feet wide, and there be an overflow of 0.66 foot above them, the load they would have to bear would be 280 pounds, and as they rest on two points of support 4 feet apart, they would have to be 0.1 foot thick. They would then only be ordinary planks, weighing from 16 to 20 pounds, which a man could very easily carry. To make them slide vertically along the trestles, assuming a co-efficient of friction of 0.50, would require a force of 140 pounds. The dam-tender can then raise them very easily by means of a simple lever, and can replace them with the same lever, which he will use, if necessary, as a maul to drive them into place.

The lower gates, which will be much higher and more heavily loaded, may be of cast or sheet iron or of wood, but the simplest and most economical method will be to make them of wood, so that they may be at once lighter and more readily kept in order. In this case they will be made of several short pieces of plank laid on top of each other and tongued and grooved, or, better, assembled with a double groove and false tonge of sheet-iron. These planks will besides be connected by vertical assembling-rods, and will all rest at their ends on two adjoining trestles.

If they are 4 feet wide and 4.25 feet high, and the head is 9.84 feet, each of the gates will have a surface of 17 square feet, and will have against a pressure of $62.5 \times 9.84 \times 17 = 10{,}455$ pounds; hence we shall have to make the usual thickness of the gates 0.27 foot. A thickness of 0.33 foot would answer for a head of 13 feet.

Consequently, the gates will not be thicker than the needles ordinarily used, and when the dam is opened the volume of wood to be taken to the store-house will not be greater than in M. Poirée's dams.

Moreover, this transportation can be accomplished by means of a small car running on the bridge; hence it will offer no difficulty and involve no loss of time. The pressure against the gates will be much reduced at the moment of raising; still if, for any reason whatever, we desired to raise them under the entire head of 9.84 feet, we should yet only require a force 5,227 pounds, allowing a co-efficient of friction 50 per cent.; hence a windlass like that at the new Port à l'Anglais Pass would be sufficient to handle them, since it can raise 6,600 pounds.

If the trestles have side angle-irons forming grooves, the gates will slide in these grooves, in the same way as mill-gates, and the planks of which they are made may be fastened together by vertical cross-pieces of wood or iron, of any shape, provided that there be an iron bar on the edge of the gate to diminish the friction on the angle-iron groove.

But if the trestles have regularly-made grooves, and they should happen to become warped, the gates might get jammed in the grooves; it would be better then to rest them against a simple shoulder, open upstream, and to fasten together the planks of each gate by two angle or T irons fastened to the sides. One of the angles of these irons will press against the up-stream angle of the post of the trestle, which need not have any special form. The very shape of the T-iron cross-pieces will increase the stiffness of the gates and prevent them from warping. Furthermore, there is no danger of their warping under the pressure of the water; they could only bend in the middle, and this can easily be avoided by making them thick enough. Nor are they more likely to warp in the store-house when out of the water, if care be taken to properly pile them on top of each other and to place a weight on the top one.

4. *Miscellaneous arrangements—automatic gates.*

Many other arrangements might be adopted for the gates. For example, we might construct a frame to hold the planking; but I do not think that the weight of the gates would thus be lessened, at least if they be of wood, and the pressure of the water would be thrown against certain special points of the trestle instead of being distributed over their entire height, and that would certainly present some disadvantages.

We might also be tempted to place rollers between the gates and their slides; but if their rollers had but a small diameter they would turn hard after being immersed a little while; besides, the entire pressure coming on the rollers, the latter would, after a while, make indentations along the upright of the trestle, over which the pressure would be badly distributed; finally, the rollers would involve, I think, losses of water that had as a rule better be avoided.

To hasten the opening of needle-dams there has been employed, in many cases, a well-known expedient, consisting in letting all the needles of a bay escape at once, after having fastened them to a rope, by means of which they are afterward picked up below; different systems of escapement have been adopted, especially on the Upper Seine, the Yonne, and the Meuse.

This expedient might, in an emergency, be applied to gates as well as to needles, and for this it would be sufficient to rest one of the sides on a key-post, forming part of the trestle, and arranged like similar posts in dams made of stop-planks.

But it would be more difficult to pick up the gates below the dam than the needles, because the former are heavier and will not float.

We might most easily, and just as rapidly, increase the water-way of the dam on the approach of a flood by inserting flutter-valves in the gates, like those added to the wickets of the navigable passes of the Upper Seine.

The gates, instead of being solid plank, would then be frames supporting a valve turning on a vertical or a horizontal axis. The ease with which the gates can be taken up in order to carry them to the storehouse, or only to place them higher or lower in the water, will permit us readily to determine by trial the best arrangement to be adopted for the valve and the position of its axis of rotation, and to test every sort of turning or even automatic valve.

We might, for example, place in the gates, and especially in those of the upper ranks, flutter-valves with a horizontal axis, or flash-valves with a vertical axis, like those in the gates of sluicing-locks, or even Chanbard constant-level valves, or any other sort of automatic valve.

This would finally resolve itself into supporting the swinging wickets of M. Chanoine directly against the trestles of M. Poirée, suppressing the horses, props, tripping-rods, &c., of the former, and consequently removing the complications which have been brought up against the Port à l'Anglais dam, where the trestles seem to do the same work as the special supports of the wickets.

We would then fully realize the amalgamation of the systems of MM. Poirée and Thénard, which M. Chanoine sought when he built the Courbeton dam.—(*Annales*, 1851, 2^e *Semestre.*)

We would preserve the advantages which the trestles present over the more complicated supports of the wickets, and also the overflow throughout the entire length of the dam, and the rapid increase of the water-way, which the wickets permit, but which are lacking where needles are used. Finally, we should avoid the difficulty of repairing the wickets.

In a word, we would thus combine nearly all the good points of all the other systems, while at the same time avoiding the greater part of their defects.

But as the gates rest thus against trestles, they should always be so small that they may be taken from the water and carried to the store-house, and it would always be necessary to have several ranks in the height of the pool unless, indeed, this height were small.

Thanks to their small size and to their position under a service-bridge, we could always open or close these turning valves by hand through the medium of a boat-hook; they would not then present the well-known disadvantages of the large automatic valves, or of those which, without moving spontaneously, must be maneuvered from the shore by submerged machinery, that it is very hard to keep in order.

The use of these turning-valves, besides allowing the water way to be rapidly increased on the approach of a flood, would lessen the force required during the maneuvers, because it is evident that, after the opening of the turning-valves, the pressure and the friction of their frames will be much reduced, no matter what may have been the head.

More than this, we can by this means completely destroy the friction, for a valve of this kind resembles, when open, the rudder of a boat, and places itself in the direction of the current. If we press on the breech, the pressure of the water will act on top of it, and it will slide along the wickets until it reaches the lower gate or the sill; if, on the contrary, we pull on the breech with a boat-hook, the pressure of the water will act underneath the valve, and make it rise along the trestles to the surface of the pool. I know by direct experiment that one man, or two at the outside, can make a gate of 10 square feet rise and sink thus along the trestles by their own strength and without the assistance of any windlass.

But this experiment is hard to perform and necessitates the use of quite a complicated valve. We must first have a frame that holds the valve which is movable about a horizontal axis of rotation, of which the position must be properly determined; then we must be able to open or close a small valve in the breech of this turning-valve, in order that the water-pressure may keep the latter open or shut, as the dam-tender may wish. All these complications will generally present more annoyances than advantages; they might, however, be useful in certain special cases, and that is why I mention them.

In general, automatic valves are very unreliable; grass or other floating matters interfere with their movements, and when they do not work of themselves, we are frequently very much embarrassed. Granting even that they work with absolute certainty, either by themselves or by means of cocks, valves, or gearing worked from the shore, they only do so under the conditions for which they are specially designed, and if, for any reason, we wish to prevent them from moving under these conditions, or to maneuver them under others, we cannot do so, and we are in a great deal of embarrassment, for it is not always prudent nor even possible to get near them with a boat.

The experience with automatic wickets on the weirs of the Upper Seine, before the establishment of trestle foot-bridges, to which they are attached by chains, was very conclusive on this point.

The dam with gates and trestles like those of M. Poirée requires no submerged machinery; the hoisting-apparatus is, on the contrary, always accessible. Hence it may be as complicated as necessary without the slightest inconvenience; in case of necessity, it might be worked by a steam-engine or by a hydraulic jack, with an accumulator placed on the shore, in which the pressure would be stored, as at the Ile Brulée dam, by means of a turbine set in motion by the fall.

Hence, as a rule, it will not be necessary to complicate valves in order to facilitate maneuvers, although, thanks to the foot-bridge and to the small size of the gates, these complications lose many of their disadvantages.

If these improvements can be of use in certain special cases, in spite of the complications they involve, we can generally be content with simple solid panels, and, in the generality of cases, we will meet every want by maneuvering these panels when placed above each other in horizontal rows.

5. *Dimensions of the trestles—height of the pools.*

No one disputes that what has thus far limited the height of trestle-dams has been the needles only, and not the trestles.

If we can remove the needles by mechanical means, either by letting them escape all along a bay, as is done on the Yonne, the Meuse, and elsewhere, or by using a windlass in a boat, as on the Lower Seine, it seems to be almost impossible to put them in place otherwise than by hand.

The maneuver to be performed in putting needles in place requires complicated motions to which a machine could hardly be adapted, and for which the intelligent strength and skill of a man are required, and, what is more serious, two men can be of little mutual assistance in placing a needle; the dam-tender must be strong enough to do it by himself. Furthermore, it does not seem to me very rational to try to maneuver the needles by a machine imitating the movements of the dam-tender. Whenever we have had occasion to do work mechanically that had previously been done by hand, we have been obliged to change the shape of the tool that the man had used and to make the machine work in a way differing entirely from hand-work. The same is true in the present instance, and it seems to me that the best way to maneuver needles mechanically is to replace them by gates.

Now, the necessity of having the needles handled by a single man gives but a very small limit to their dimensions, and consequently to the height of the dams. Thus, the maximum height of M. Poirée's dams seems to be nearly reached on the Lower Seine, at Martot, Suresnes, &c., where the pool rises to 9.84 feet above the sill; it is certainly reached on the Meuse, where this height is 11.48 feet.

Again, these heights are only reached on the Meuse by means of escapements, and on the Lower Seine by making the needles bear against the points of support by means of the intermediate sustaining or relieving bars first used by M. Marini at the dams of Bezons and Andressy. But the handling of these sustaining-bars is very tedious, difficult, and even dangerous.

The height of the dams of MM. Desfontaines, Girard, and others, is still more limited. As to M. Chanoine's dams, besides the considerable complications inherent to this ingenious system, the horses, the props, and the wickets themselves would attain disproportionate dimensions, and their weight would become very great if the pool exceeded a certain height. However, the limit of height that dams of this kind can reach has not yet been attained in practice. It seems that it can exceed 13.12 feet, and possibly even 14.76 feet; but the cost of construction increases very rapidly with the height of the pool.

In a dam with trestles and ranks of ordinary gates, it seems to me demonstrated by what precedes that the height of the pool cannot be limited by the gates, since their maneuvering will always take place under very nearly the same conditions, whatever be the number of ranks that we may have to place on top of each other.

As to the trestles, they may be very large without inconvenience. Those at Port à l'Anglais are already 16.40 feet high by 9.84 feet base, and weigh 1,320 pounds apiece. They are handled without difficulty by means of a light windlass. Experience as well as calculation shows that we might make them much larger yet.

But I must here answer an objection that has been made to me about my notice of the Port à l'Anglais dam. Some engineers have doubted whether it could be necessary to make pools of more than 13.12 feet or 14.76 feet above the sill, and I cannot agree with them. Since movable dams have been established—that is, since the almost simultaneous inventions of M. Thénard, in 1831, and M. Poirée, in 1834—the height of the pools of these dams, as they were successively constructed, has always been increased, and I think we are still quite a distance from the maximum height that it may be necessary to give to movable dams.

Up to the present time the height of the pools, and consequently the projects for slackwatering rivers, have always been subordinated to the kind of dam to be employed. Thus, in 1844, M. Sermet prepared the first project for slackwatering the Upper Seine with dams, each of which raised the water 7.54 feet above the sill. Later, M. Chanoine changed this project so as to use everywhere a style of dam 9.84 feet high. The same very nearly uniform height of 9.84 feet has been adopted on the Marne and the Yonne. Finally, M. Krantz quite recently published (1871, Monrocq, rue Suger, Paris) a project for slackwatering the Lower Seine by means of dams 13.12 feet high; and in all these plans the levels of the pools were far from rising to the height of the banks. On page 61 of the memoir just mentioned, M. Krantz explains that the banks of the Seine are everywhere 3.28 feet higher than the pools, and that it would be easy and inexpensive to raise this height to 4.92 feet, by raising some low parts of the tow-paths 1.64 feet higher. Now, it appears to me that a project for slackwatering should not be subordinated to the height of the machines for closing the dams, but that other more important considerations should determine the positions and heights of the pools. When a dam is built, it is evidently a matter of great importance to raise the water as high as possible—that is to say, to the level of the banks—even though the cost of constructing the dam should be much increased. We should thus reduce the number of locks, even if we did not increase the draught of water; and this is very important, because the construction, maintenance, and maneuvering of a lock is always much more expensive than similar work on a dam. In every case it is a great advantage to the boating interest to have one lock less to pass.

So far as the Seine is concerned from Paris to Rouen, an increase in the depth of water offers such an inducement that the attempt will certainly be made at some time in the future to raise the pools as much as the level of the banks will allow, and even in 1827, M. Frimot, in a very remarkable paper to be found in the library of the school of the *Ponts et Chaussées*, proposed to give the Lower Seine a draught of 16½ feet by means of 10 dams with locks raising the water to the level of the banks.

In fact, there is no reason for not raising the pools of great rivers to a level with the banks as is done on small streams by regulating the water powers, and on a river of steep slope and revetted banks there might be a necessity for establishing movable dams of very great height.

Hence I think that it would be very useful to be no longer limited in the construction of movable dams by the height of the apparatus for closing them, and I think that a dam of trestles and ordinary gates will be able to reach all necessary heights.

It would evidently be easy to raise the pools very high with quite small apparatus, by placing the permanent sole above low water, as M. Thénard did on the river de l'Isles; but this solution has been very justly rejected by the council of the *Ponts et Chaussées*, as stated by M. Saint-Yves in his article of 1870, (*Annales*, November, 1870, page 439,) and, in fact, it seems necessary, from all points of view, to preserve on the sills of the passes of the dams the same natural depth of water as on the bars in the immediate neighborhood.

6. *Resistance of the trestles.*

It is easy to assure ourselves that we can always make the trestles sufficiently strong to support a very high pool.

A trestle is a straight vertical frame embedded at its base and supporting almost horizontal pressures. The resultant of these pressures is transmitted to the journal-boxes at the base, the down-stream one having both a horizontal thrust and a vertical pressure, while the one up-stream must resist a vertical pull.

The down-stream journal-box and the masonry of the floor will always be able to sustain the compression to which they are exposed, whatever may be its magnitude; as to the vertical pull on the up stream journal-box and on the sill to which it is fastened, we can always reduce it to a suitable amount by sufficiently lengthening the axle of the trestle. Besides, we might, by properly anchoring the sill or by fastening its journal-boxes to a cast or plate iron beam bedded in the floor, allow a greater pull on the up-stream journal than the 7,480 pounds allowed at Port à l'Anglais, which has been shown by experience to be unobjectionable. Finally, it will be easy to greatly diminish the pull on the sill, without disproportionately increasing the base of the trestle, by slightly inclining its up-stream post and the gates that rest upon it. I have shown, in the report on the new Port à l'Anglais pass, that we can thus diminish the pull on the sill of the wickets by slightly increasing their length and the total pressure against them. The question here is exactly the same.

A very simple calculation shows that, to completely do away with the vertical pull on the sill of the trestles, it will be sufficient to incline the gates that they support at an angle of 15 or 20 degrees, and to make the base of the trestle very nearly as long as it is high. Moreover, the pressure on the down-stream journal diminishes at the same time with the pull on the up-stream one.

Furthermore, it is easy to show by calculation that, if we neglect the projection of the sill above the base of the trestles, the reaction of the points of support will be absolutely the same, whether the pressure of the water be spread over the entire height of the trestle by means of stop-planks or gates, or one-third of it be carried by needles to the top of the trestle. Taking into account the projection of the sill, the points of support are slightly more loaded by the gates than by needles, but less than if the sill were cut down to the level of the journal-boxes, and for a very high pool it would still be only necessary to make the journals of the trestles quite small.

This would not be the case with the axle, and we should have to give it a very great diameter for high lifts, if we continued to make it of round iron, like the ends that form the journals. But this axle is a straight beam resting on two points of support, and acted on by two forces applied very near these points, where the up and down stream posts join it. This beam will always offer a sufficient resistance if we make it an **I** beam, and attach journals at the ends.

As to the upper part of the trestle, it might be made lighter if it were loaded by gates than if it supported needles, for if we consider any horizontal section of the trestle and seek its bending moment, (except at the level of the lower pool, where it is zero, and at the base of the trestle, where it reaches its maximum,) this moment will always be less if the pool be formed by planks or gates than if formed by needles, and for one of the sections the moment due to the gates may only be the one-third of that produced by needles.

The part of the trestle raised above the upper pool to lift the foot-bridge above unforeseen waves may be very light, for it will support no water-pressure, and from the level of the upper pool to its base the trestle should have increasing cross-sections. Its center of gravity will then be low enough, and it will be lower with gates than with needles. Hence we shall always be able to handle it with quite a light windlass, even when it is very large and very heavy, because the lever-arm of the power will be greater just as the weight to be moved increases.

For large trestles sustaining gates the cross-bars become more important than if needles are used; one brace will no longer be enough, and the trestles will have to approach the shape of lattice-girders; we shall also have to use bar-iron of special shapes in order to obtain as great a transverse resistance as possible, because the defect of very high trestles is that they are not braced across the current between their top and bottom.

For this last reason we shall have to build trestles like those on the Saône or at Port à l'Anglais, with **U** or **I** iron, and reject **+** or **T** iron, of which the transverse resistance is much less.

As to the general shape of the trestle, it should be studied for each particular case; but the ordinary shape of trestle intended to support needles would no longer suit for a tolerably high pool; the transverse pressures on the up-stream post developed by the gates would tend to make it bend. It is true that the horizontal cross-bars would oppose this change of shape, but they would do it by making transverse pressures on the single brace and on the down-stream post, both of which would be similarly exposed to bending. The form of a Saint Andrew's cross, adopted for the trestles of the weirs of the Upper Seine and for those at Port à l'Anglais, would no longer be suitable, for it was originated solely by the necessity of sustaining the pressure of the down-stream wheels of the maneuvering windlass; the arm of this cross leaning down-stream would assist very little in resisting the pressure of the gates, and, as far as the windlass is concerned, there is no need of carrying this arm down to the base of the trestle.

For these reasons I think that the most simple and rational shape for trestles intended to sustain several ranks of sliding gates would be that of a series of trapezoids, one above the other, their heights being the same as those of the gates.

Thus, just as we placed several gates on top of each other to form the pool, so we would place several Poirée trestles on top of each other to sustain these gates; the top trapezoid alone, situated above the upper pool, would have a Saint Andrew's cross to support the windlass, and the lower trapezoids would have but a simple brace.

Fig. 4 of the plate shows this arrangement; and as it forms a simple truss, it is easy to calculate the resistance of the different parts composing it: L C being the level of the upper pool, C E and E G two contiguous gates, the pressure R on the upper gate will be decomposed into two other parallel forces, P, applied at C, and Q, applied at E.

If α be the angle, supposed equal, between both posts and the vertical, β the inclination of the brace C F, the force P will produce a pull on the post $C\,E = P\,\frac{\cos(\alpha+\beta)}{\sin(\alpha+\beta)}$, and a compression on the brace

$$C\,F = \frac{P}{\sin(\alpha+\beta)}.$$

At the point F the pressure of the brace C F gives:

$$\text{A pull along } E\,F = P\,\frac{\sin(\beta-\alpha)}{\sin(\alpha+\beta)\cos\alpha},$$

$$\text{A compression on } F\,H = P\,\frac{\cos\beta}{\sin(\alpha+\beta)\cos\alpha}.$$

Thus we can easily calculate the dimensions of the different parts of the trapezoid C D E F, in which C D and F only serve, as in the top trapezoid, to support the foot-bridge and its windlass.

The pressure of the second shutter, E G, will be in like manner R′, and will be decomposed into two parallel forces, P′, applied at E, and Q′, applied at G; hence we shall have at the point E the forces Q and P′ and the tension E C and E F, of which the resultant will determine the tension on E G and the compression on E H, and so on.

We may remark that if the posts of the trestle were vertical, that is, if α were zero, the tension on the post E C and the compression on the post F H would be equal to each other and to

$$\frac{P}{\tan\beta},$$

and the tension on the cross-bar E F would be equal to P, and as, on the other hand, the forces R and R′ would be horizontal, we should have a the point E only the vertical force

$$\frac{P}{\tan\beta}$$

and the horizontal force R + P′. Hence, to calculate the tension on E G and G H and the compression on the brace E H, it would be sufficient to transfer parallel to itself to the point E the pressure R of the upper gate. Finally, by inclining the up and down stream posts from the vertical, we reduce to a certain degree the strains on all the parts of the trestle; the tension C E in the ratio of

$$\frac{\tan\beta}{\tan(\alpha+\beta)};$$

the comparison C F in the ratio of

$$\frac{\sin\beta}{\sin(\alpha+\beta)};$$

the component of the tension E F normal to C G in the ratio of

$$\frac{\sin(\beta-\alpha)}{\sin(\alpha+\beta)}, \text{ \&c.}$$

Objections may be taken to the arrangement shown in Fig. 4, in that it does not furnish sufficient transverse resistance when raising the trestles at the horizontal sections adjacent to the cross-bars, but this defect is easily remedied by large bracket-plates set at the junction of the cross-bars and of the braces with the posts. Still it may, perhaps, be necessary for very high trestles for this reason, and also that the braces may not be too much loaded, to replace the truss of Fig. 4 by a regular lattice-truss, arranged as in Fig. 5 or even Fig. 6.

If we adopt these arrangements, the calculation will be more difficult; it will even be indeterminate on account of the connections between the pieces which cross each other; we shall, however, be able to make it by means of certain hypotheses, as we do in the case of the lattice-girders of plate-iron bridges. In this case it would be well, in order not to cut the crossing pieces, to keep the ⊔- or H-iron for the frame and for the inclined braces; as to the horizontal cross bars, which are under a tensile strain, and consequently do not need such great transverse resistance as the pieces under compression, they might be made of two pieces of flat iron embracing the others, like double binders, Fig. 7. As to the up-stream post, it may be made of a ⊔-iron, on which could be riveted a T-iron; this T-iron would form the groove to receive the gates, and it would overlap laterally the ⊔-iron, so as to cover the connecting bracket-plates of the cross-bars and their rivets, which might interfere with the sliding of the gates, (Fig. 7.)

Finally, a greater degree of stiffness might be given to the braces by making them of two channel-irons placed back to back, as at Port à l'Anglais, and setting these two irons a little apart and fastening them together here and there by rivets running though sleeves, (Fig. 8.)

7. *Longitudinal bracing between the consecutive trestles—Subsequent raising of the level of the pool.*

An objection can be made against using trestles of great height that they are not sufficiently interbraced in a direction across the current, for they are only connected at top and bottom by the foot-bridge and the floor.

By substituting gates for needles, the trestles will be completely joined together on the up-stream side from the bottom to the top. We might even furnish the down-stream posts with slides in which we could let down gates similar to those used at the up-stream posts, or simply open-framed gates; the interbracing would then be complete on the down-stream as well as on the up-stream side.

This arrangement would amount to dividing the fall into two parts, and if the total fall were great, we should thus diminish the scour to a certain extent, since the destructive force of the fall would be deadened by two successive falls. Besides, by employing two successive sets of gates on the up and down stream sides of the trestles, we would considerably lessen the pressure on each of the gates, and their weights and thicknesses would consequently be diminished, and maneuvering would be still further facilitated by his expedient, but the time required would probably be increased.

A similar mode of dividing the fall of a dam by two successive sets of gates has already been successfully tried at the contiguous dams of Château Thierry on the Marne, where M. Jozon, in order to increase the height of the pools, contented himself with placing needles against the trestles, from the top of which the Chanoine wickets, placed on the down-stream side, are maneuvered. This engineer could thus use very long needles without unreasonably increasing their sectional area and weight, because, thanks to the wickets below them, these needles only supported a small part of the head. Moreover, he was able to increase the lift of the dams without changing the wickets, because the trestles support the excess of head that the wickets could not have held, not having been made for that purpose.

This example of the Marne shows that we must sometimes increase the height of a dam after its construction, and this condition has in fact already occurred several times; a good many dams have even had to be entirely rebuilt for this reason, particularly the dam at Bezons.

The dam with trestles and gates presents a very marked advantage over all others from this stand-point; for if in the beginning the foundations have been laid under proper conditions of stability, and if the trestles have been made sufficiently strong, we have only to place a plank above the gates in order to increase the pool proportionately to the necessities that may subsequently arise. Even if we should afterward wish to greatly heighten a dam of this kind, we could do so without very great expense, since it would be sufficient to replace the trestles, and the old ones could be utilized elsewhere.

In every case where a dam is built of which the pool does not rise to the level of the banks, it would be well to give an excess of strength to the trestles, in order to permit, in case of necessity, the temporary or permanent raising of the pool.

CHAPTER II.

APPLICATION TO THE DAM AT PORT À L'ANGLAIS—EXPERIMENTS.

1. *Arrangements adopted for the experiments.*

General arrangements.—The mode of closing movable dams described in the preceding chapter has been applied as an experiment to the deepest pass of the Port à l'Anglais dam, and for this it was sufficient to place ordinary gates against the trestles supporting the service-bridge of this pass.

The Port à l'Anglais pass was described in number of the *Annales* for August, 1873. Plate 20 of 1873 shows the arrangement of the whole, and plate 21 shows specially the navigable pass of which the trestles now support the sliding gates; the plate accompanying this article only reproduces these trestles, and shows the means adopted for raising and setting these gates in place.

I shall merely mention that the new pass at Port à l'Anglais has a water-way of 94.16 feet; it is closed by 26 wickets, of M. Chanoine's system, which are maneuvered by a windlass running on a foot-bridge composed of 26 trestles.

The level of the upper pool is constantly kept at 12.47 feet above the sill, and sometimes rises to 13.45 feet; the fall varies with the natural height of the Seine below the dam; it was as much as 10.20 feet in September, 1874.

Trestles.—The trestles are 15.58 feet high from their lower journals to the foot-bridge, 10.17 feet wide at the base, and 3.94 feet at the top; they are 3.61 feet apart from axis to axis. They are made of ⊔-iron $3\frac{1}{8}$ base, $1\frac{5}{16}$ height, and $\frac{3}{8}$ thickness. The up-stream post, therefore, has a flat face $3\frac{1}{8}$ inches wide, on which the two gates have a bearing of $1\frac{7}{32}$ inches at the ends, leaving a play between them of $\frac{1}{16}$ inch. The breadth of support of $1\frac{7}{32}$ inches is rather small; still no trouble has thus far resulted from it, and, moreover, it will be easy to make the trestles a little thicker and to separate the adjoining gates by riveting a T-iron on the front part of the up-stream post, as I have pointed out in the preceding chapter. Lastly, the ⊔-iron on which the gates rest has on its side faces projections caused by the assembling plates or brackets of the cross-bars, and by rivets which are of such a nature as to interfere with the sliding of the gates, or at least to very greatly increase the friction; it would be easy to avoid this inconvenience in the construction of another dam by making the T-iron just mentioned overlap the assembling plates and their rivets, as shown in Fig. 7 of the plate.

Gates.—Three gates of oak, 3.54 feet wide by 4.25 feet high, are placed on top of each other in each bay included between two adjacent trestles, or, in all, 81 gates for the 27 bays. This system of gates rises to 12.79 feet above the sill, or to 0.33 foot above the ordinary level of the pool, provided that the entire discharge of the river flows ordinarily through the spaces included between the swinging wickets which close the other two passes of the dam.

Each gate is composed of five planks 3.54 feet long and 0.85 foot wide, joined by a double groove and false tongue of sheet-iron and stiffened by two T-irons bolted near the ends. These T-irons are 4.26 feet long, and measure 4 inches base, $1\frac{3}{4}$ inches height, and $\frac{3}{8}$ inch thick; one of their angles embraces the corresponding angle of the ⊔-iron of the trestle. When the gates are maneuvered the T-irons form slides and rub against the ⊔-irons of the trestles; the ends of the former are slightly curved, and that has sufficed to prevent them from catching in the bracket-plates of the cross-bars of the trestles, (figures 10 and 11.)

The gates of the two lower ranks are 3 inches thick, and those of the upper rank only $2\frac{1}{2}$ inches; finally a certain number of them have iron handles, of the model shown in the drawing, (figure 2.)

Through motives of economy the handle has been omitted on the others, and replaced by an iron chain fastened immovably to the gate at one end, and at the other attached to the service-bridge or to the maneuvering windlass. These chains were lying in the store-house of the dam, and their employment involved no expense.

Through the same motives of economy the T-iron slides have been replaced by oak guides on a certain number of gates, and this gives no trouble, provided these gates are maneuvered when the fall has almost disappeared.

Light gates at the top of the pool.—On the other hand, instead of placing in all the bays three gates, made uniformly of five planks 0.85 foot high, a certain number of gates of the middle and the top rank had the planks reduced to four, so that they were only 3.41 feet high instead of 4.26 feet, and the closing of these bays was completed by small gates, or mere boards 0.85 foot or 1.70 feet high, which usually sufficed to regulate the pool during low water.

These thin little gates being placed at the top of the dam, the lock-tender very easily places or removes them by hand without the aid of any windlass, but he is oblighd to press them out with a lever, so as to make them clear the bolts on the up-stream side of the trestles that fasten the standards of the hand-rail of the foot-bridge. These bolts and standards, shown in Plate 21 of 1873, but omitted in the plate hereto annexed, interfered with all the maneuvers of the gates in the experiments at Port à l'Anglais; but it is evident that they could also be suppressed by moving the hand-rail to the down-stream side.

Hoisting-apparatus.—The hoisting-apparatus is merely the windlass ordinarily used in maneuvering the wickets below the trestles, and which was shown on Plate 21 of 1873. To this windlass is attached a small gin which only serves to hold, raising it to a proper height, a guide-pulley required in raising the gates. Another pulley used in lowering the gates to the bottom is fastened to the gin on the frame of the windlass. Finally, the gin has a small crane, by means of which the gates are taken, when raised above the water, carried around on the foot-bridge and laid on the little service-wagon, and *vice versa.* This little crane obviates the necessity of turning the windlass itself on the bridge, because that would have required its being replaced by a new crane on a vertical pivot.

The arrangement of the gin, adopted for economy, has the great inconvenience of obstructing circulation on the bridge, because formerly we could pass from one side of the windlass to the other through the space now occupied by the gin; but this now closes this passage. But it is evident that this trouble could be easily remedied by turning the windlass end for end and placing it in the position shown in Plate 21 of 1873, and putting the gin, or rather the supports of the upper guide-pulley, above the cast-iron cheeks, which carry the windlass and its gearing. This arrangement could not be adopted at Port à l'Anglais, where we wished to use the windlass, as originally made, without radically changing it; but this could be elsewhere; and, furthermore, it would be very easy to widen the foot-bridge, which is very narrow at Port à l'Anglais, even should we have to do so by means of corbels fastened to the down-stream posts of the trestles.

Cost of construction.—The sum appropriated for constructing the gates intended to throw, if necessary, on the trestle at Port à l'Anglais the pressure usually sustained by the Chanoine wickets established below, was fixed at $1,100 by a ministerial decision of November 24, 1874, and the economical measures above mentioned have enabled us not to overrun it.

But very nearly one-fourth of the allotment was absorbed by a construction independent of the gates themselves.

Plates 20 and 21 of 1873 show that the new pass is separated from the weir by two piers, between which the trestles of the new pass fall. To throw on these trestles the water-pressure supported by the wickets, it was necessary to close the vacant space between the piers by means of a large fixed barrier, of which the construction and placing were quite difficult and troublesome, because the masonry of the piers was not arranged to receive it, and it had to be deflected outward toward the weir so as to allow the first trestle of the pass to fall. The presence of the float of the weir, projecting into the space to be closed, further complicated this construction.

Each gate of 4.26 feet by 3.54 feet and 3 inches thick is composed of 3.96 cubic feet of oak, and 96.8 pounds of iron for the T-slides, the handle, the sheet-iron tongues, and the bolts; hence each one weighs about 264 pounds, and costs nearly $12, viz:

3.96 cubic feet of wood, at $1.02 per foot	$4 04
96.8 pounds of iron, at $0.082 per pound	7 94
Total	11 98

Eighty-one gates of this size were needed for the pass at Port à l'Anglais, and would have cost altogether $970.38, if all these gates had been built on the most expensive model; adding $28 for the gin on the windlass, we reach a total expense of about $1,000, or for 94.16 running feet $10.62 per foot.

The timber and iron-work of the wickets, trestles, sills, floor, tripping-rods, &c., of this new pass cost in 1870 $11,975.85, (*Annals* 1873, 2*e Semestre*, p. 138;) and analyzing this amount we find it composed of $4,308.10 for the trestles and accessories, or $45.75 per running foot, and of $7,667.75, or $81.43 per running foot, for the wickets and their accessories.

If then the Chanoine wickets had been replaced at the beginning by plain gates resting against the trestles, the movable apparatus for closing would have cost only $45.75 + 10.62 = $56.37, instead of $45.75+81.43= $127.18 per running foot, giving a saving of $70.81 per running foot for these parts alone.

On the other hand, leaving out coffer-dams and pumping, the masonry and earthworks of the new Port à l'Anglais pass cost, in 1870, $7,856.10, (*Annals*, 2*e Semestre*, 1873, p. 138,) or $83.43 per running foot. Now, the existence of both trestles and wickets has required the floor to be 52.59 feet wide, measured in the direction of the current, and if we notice that of this width 21.32 feet around and about the wickets had to be of cut stone, it will readily be seen that by suppressing them we could have reduced the width of the floor and saved at least one-fourth of the cost of the masonry, or $20.86 per running foot. We should thus have had a total saving of $70.81 + 20.86 = $91.67 per running foot; that is, nearly 30 per cent. of the total cost, which reached $314.09 per running foot.

Hence we are justified in believing that if we were to adopt the new system, instead of the one used in 1870 at Port à l'Anglais, to close a dam like that of Port-Villez, whose length is 394 feet, all other things being supposed to be equal, we would realize a saving on this structure of about $36,000.

Finally, we may remark that the new Port à l'Anglais pass having cost $314.09 per running foot, if we subtract $91.67 from this amount, we have a remainder of about $222. Now, the cost of constructing the 12 dams of the Upper Seine, between Montereau and Paris, gives as a mean, per running foot of pass closed by wickets 9.84 feet high, $187.18, (*Annals* 1868, *2e Semistre*, page 408;) hence the new mode of closing allows us to have 13.12 feet of backwater instead of 9.84 feet, at an *average* increase of cost of $35 per running foot, or only one-fifth.

2. *Experiments.*

Nature of the experiments.—It was not possible, in the experiments at Port à l'Anglais, to maneuver the gates in the logical and rational order given in paragraph 2 of the first chapter, and to take up or replace all those in the same horizontal row before passing to the next, so as only to work with small falls, because the circulation of boats is much too active in the two levels separated by the dam to allow their respective levels to be changed. The operations could only be conducted in this way at the time of the general maneuvers of the dam, which nowadays are very rare. Hence we were obliged, in these experiments, to take up and then replace the three gates of a vertical section between two adjacent trestles, and although we were thus placed under very disadvantageous circumstances, quite different from those of actual service, and the arrangement of the trestles and the windlass were imperfect, this maneuver has been frequently performed without difficulty under a very heavy fall; the experiment is therefore only the more conclusive.

This maneuver was performed, especially April 3, 1875, before M. Cambrozat, inspector of the division, and MM. Leferme and Rougeul, chief engineers, with 12.40 feet depth of water in the upper pool and 4.85 feet in the lower, and consequently under a fall of 7.55 feet; on April 9, before MM. Kleitz, Kolb, Graeff, Chatoney, and Duverger, inspectors-general, with 12.40 feet in the upper pool and 4.23 feet in the lower, and a fall of 8.17 feet; finally, on the 4th of May, before several inspectors and engineers and students of the École des Ponts et Chaussées.

When this last experiment was tried, a certain number of joint-covers were in place, over the intervals between the wickets below the trestles, so that the water rose between the gates of the trestles and the wickets as the gates were taken out. All the gates being placed against the trestles, the water rose to 12.40 feet on the upper sill, to 5.25 feet between the gates and the wickets, and to 3.71 feet below the latter; but when the three gates of a bay were removed the water rose to 6.56 feet on the up-stream side of the wickets, and there was only 5.84 feet fall when the bottom gate was returned to its place. On the 3d and 9th of April there were no joint-covers on the wickets, and the level varied very little below the trestles.

This observation already shows that the dam with the trestles is much tighter than that formed below by the wickets, and in fact, when the gates are properly put in place, the leakage is very small.

When all the gates are placed against the trestles, the water falls at once between them and the wickets. On the 3d of April there was a difference of level of only 4 inches between the upper and lower side of the wickets, while the gates supported a head of 7.54 feet; on the 9th of April the same falls were 0.43 foot for the wickets and 8.17 feet for the gates; finally, on the 4th of May, when a bay, 3.61 feet wide, had been removed for a height of 12.40 feet, and a certain number of joint-covers were over the spaces between the wickets, the gates supported a fall of 5.77 feet and the wickets only 2.85 feet.

Raising the gates.—Figures 1 and 2 of the plate show the raising of a gate. If it be supplied with a chain, the lock-tender hooks it to the chain passing over the upper pulley of the gin; if, on the contrary, the gate has merely a handle, the lock-tender hooks the chain of the windlass to the socket of his maneuvering staff; then he throws it up-stream so that it may rest against the gate; he then raises the staff, of which the hook comes against the handle, and, by reason of the shape of the latter, fastens itself thereto.

It is sufficient to work the windlass until the gate is raised just clear of the water; it is then taken by the tackle attached to the small crane, and on turning the latter the gate is lowered either to the bridge or on a small transporting wagon.

Putting the gates in place.—To put a gate in place it is brought to the windlass on the little wagon; it is then raised with the tackle of the crane; the latter is then turned and the gate is lowered against the trestles by its own weight until it is more than half submerged, and the pressure of the water prevents it from sinking farther. If it be a gate of the upper rank, it is sufficient for the lock-tender to bear down on it with his foot to place it in contact with the gate of the second rank. For the bottom gates a rod or wooden staff is used, having a fork at the end that will embrace the gates, and to the upper end of this staff the chain of the windlass is fixed after passing it around the lower guide-pulley, as shown by Figure 3.

It is then sufficient to work the windlass to make the gate descend under the water, and it is known that it has reached bottom when a mark on the staff comes flush with the bridge.

In the drawing the staff seems to be unguided in its motions; in reality it leans a little down-stream, and rests successively on the different transoms of the gin, and as that causes a good deal of friction, it would be well to support it on rollers attached to the gin.

Various arrangements of the windlass.—This result might be easily obtained by replacing the gin by a pair of guides like those of a pile-driver, and set in the same plane as the up-stream face of the trestles, and which would act to guide the staff intended to push down the gates.

In order that the pressure on the gates may be always normal to their breadth, and that they may not lean toward either trestle, thus greatly increasing the friction, we might use two parallel staves connected by transoms like a ladder; each of these staves would be directed by one of the guides. Besides, we might place at the foot of the ladder a longer transom resting on the two adjacent trestles like the gates themselves, and this transom might have a snap-hook which would catch by itself in the handle of the gate to be moved.

The ladder would thus serve to raise as well as to send down the gates; the snap-hook could be movable and taken out when a gate is to be sent down. Furthermore, the ladder might be maneuvered either by a chain passing at one time over the upper pulley and at another over the lower, or else by means of a rack fastened to the ladder and gearing into one of the pinions of the windlass. It would be easy to throw this rack or the windlass itself out of gear, if we wished to use the ladder as a ram to strike upon the gates and to send them down more rapidly. But these blows might cause trouble, and it would be well in this case to let the maneuvering ladder fall from only a small height at each blow.

Finally, as the gearing uses up a great deal of power in friction, it might be replaced by a small hand-pump, and a hydraulic jack, placed between the guides, would take the place of the rack. The stroke of this jack might be short, or about equal to the height of the gate; the rounds that join the two uprights of the ladder would be replaced by bolts or movable keys, and their distances apart would be equal to the stroke of the piston. One of these keys would pass through both the uprights of the ladder and the piston of the jack, and when the latter had reached the end of its stroke it would be run back to the next key; the gate, during this change, would evidently be held immovable against the trestles by the mere pressure of the water.

We will remark in this connection that the gates, being always in stable equilibrio against the trestles, will never cause any of the dangers to the lock-tenders that are incident to Poirée needles and Chanoine wickets. The latter, on the contrary, leave their supports suddenly during the maneuvers, and if the lock-tender be lacking in attention or skill, or does anything imprudent, he receives a violent shock and is sometimes thrown into the river; nothing of this kind is to be feared with gates which are always in equilibrium on their slides, so long as they are under water.

Length of the maneuvers.—We noted the time required in maneuvering the gates during the various experiments, and the result, as might be expected, was very nearly the same for raising as for lowering the gates. From 2 to 3 minutes was required to raise a gate 3.54 feet × 4.26 feet = 15.07 square feet of the top rank. The maneuvring of the lower gates was much longer, as it had to be performed at Port-a-l'Anglais, under the total fall of the dam; it required 5 to 6 minutes for a gate in the second rank, and from 8 to 10 minutes for one in the bottom rank under a heavy fall; but this last maneuver is very rarely necessary in practice. On the contrary, we remarked in the first chapter that the gates in the lowest rank have the least pressure against them when it comes their turn to be moved.

Be that as it may, we see that we may open or close in 15 to 19 minutes at most, a bay in the dam of 12.47 feet × 3.54 feet = 44.14 square feet. At Suresnes 100 to 120 needles are taken out or replaced in an hour, or 2 needles per minute, and the water-way is thus made to change 9.84 feet × 0.66 foot = 6.16 square feet per minute. The maneuvering of the gates of the upper rank at Port-à-l'Anglais thus gives about the same water-way per minute as the maneuvering of the needles at Suresnes. As to maneuvering the gates of the lowest rank as was done during the experiment at Port-à-l'Anglais, it cannot be compared with that of needles, because the latter have never, to my knowledge, been maneuvered with a depth of pool of 12.47 feet and a fall of more than 6.56 feet.

The wickets, 9.84 feet in height, of the navigable passes of the Upper Seine, fall almost instantaneously by means of the tripping-rod, but 10 minutes on an average is required to raise one with the maneuvering-boat, and to reduce the water-way by 9.84 feet × 3.94 feet = 38.77 square feet; it must also be noticed that they can only be raised when the fall is small. It would be altogether impossible to raise a Chanoine wicket under the entire fall of the dam, as is done with the gates at Port-à-l'Anglais. It can only be done by first covering the position of the wicket by a temporary timber screen or scaffolding, and that requires, relatively, a great deal of time, generally several hours.

Perhaps the conclusion will be formed from these experiments that the handling of the sliding-gates is too slow, and that this is a defect of the system, but that it might be lessened. A man working at a windlass can only gain power at the expense of speed, and that is why we have mentioned the possibility of replacing the windlass by a hydraulic jack.

The jack is generally a very slow tool, because only one man acts at the pump; but it will be noticed that this pump will only act intermittently during the maneuvers, and if we place a pressure-reservoir or accumulator alongside, we can work steadily at the pump and then expend in one minute, at the instant of maneuvering a gate, the power accumulated during the 2 or 3 minutes in which the windlass was at rest for hitching to or unhitching from the gate, &c., and I think that the maneuvers will be greatly hastened in this way.

We might add that there are now to be found almost everywhere small steam-windlasses combining great speed with great power, and which take up scarcely any more space than the hoisting apparatus now used which is shown in the plate, and that the motive power furnished by a steam-engine is certainly more economical than that generated by men working at a windlass. But I do not think that these complications will be necessary except in special cases, for I have already stated that we need never be in a great hurry about maneuvering a dam made of trestles and gates, since only a small part will be maneuvered at a time.

On the other hand we shall only have to vary the water-way in proportion to the changes in the discharge of the river, and on the other hand the overflow of the water throughout the length of the dam will give a wide margin for the duration of the maneuvers.

The removal of a gate of 4.26 feet from the top rank of a dam causes an increase in discharge of at least 91.93 cubic feet per second; taking away the first rank of gates will consequently increase the discharge per second by 91.93 cubic feet in 2 minutes, or by more than 2,700 cubic feet in an hour; it is not probable that the discharge of the river will increase so rapidly, and besides, if that did happen, the discharge by overflow throughout the entire length of the dam would also increase and the pool would only rise very slowly.

By afterward raising the gates of the second rank 4.26 feet high, we shall, in 8 or 10 minutes, increase the discharge per second by at least 175 cubic feet, if this gate be not under water from below. The total discharge will then be nearly 62.67 cubic feet per running foot of dam after taking out the second rank of gates; it is evident that the fall will almost entirely disappear, and that we will have all the time needed to proceed to the raising of the third rank; besides it is very probable that this last maneuver will not be immediately necessary. Furthermore, if the discharge of the river increases so fast, the fall of the dam will rapidly diminish, and the maneuvering of the middle and bottom ranks of gates will be quicker than it could be at Port à l'Anglais under a fall of more than 6.56 feet. Finally, if we have to deal with such large discharges, the length of the dam will be very great and we can then use two sets of hoisting apparatus and employ two crews to work them.

Friction of the gates on the trestles.—Some experiments were made to determine, by means of a dynamometer, the value of the effort required to raise the gates. For this purpose we used a Régnier dial dynamometer, belonging to the École des Ponts et Chaussées, by setting it between two links of the chain used for raising the gates. But in order not to overload this instrument, the chain coming from the upper pulley of the gin (figure 1) was rove through a movable block. The gate to be lifted was then fastened to the shell of this block, and the end of the windlass-chain after passing around this block was made fast to the upright of the gin; the dynamometer placed near this fixed point remained immovable, and it could always be observed with ease, and its indications gave half the force used on the gate. In spite of this arrangement strong pulls could not be tried without danger to the dynamometer, and thus we only experimented on small falls.

I shall mention only three of the experiments made, one for each rank of gates, selecting those which were made under the greatest pressures.

1st. *Gate of the upper rank.*—The water stood, at the time of the experiment, 12.53 feet above the sill, or 4 feet above the bottom of the gate in hand, which was out of water on the down-stream side; the hydrostatic pressure against this gate, 3.54 feet wide, was, therefore,

$$62.5 \text{ pounds } \frac{\overline{4.00}^2}{2} \times 3.54 \text{ feet} = 1770 \text{ pounds.}$$

The dynamometer marked an initial force of 990 pounds, which rapidly diminished; the weight of the gate was 264 pounds; the resistance due to friction was 726 pounds, and the coefficient of friction,

$$\frac{726}{1770} = 0.41.$$

2d. *Gate of the second rank.*—The water stood at 12.50 feet in the upper pool, and at 6.07 feet in the lower pool above the sill, or at 8.23 feet in the upper pool, and 1.80 feet in the lower pool above the bottom of the gate experimented on; this gate being 4.26 feet high and 3.54 feet wide, supported a hydrostatic pressure of—

$$62.5 \text{ pounds} \times 3.54 \left[\frac{(8.23 - 4.26) + (8.23 - 1.80)}{2} (4.26 - 1.80) + (8.23 - 1.80) \times 1.80 \right] = 5391.25 \text{ pounds.}$$

The dynamometer oscillated from 2,508 to 2,860 pounds in raising the gate 0.36 foot, the effort due to the friction was, consequently, at the outside, $2860 - 264 = 2596$ pounds, the gate weighing 264 pounds; hence we find the coefficient of friction,

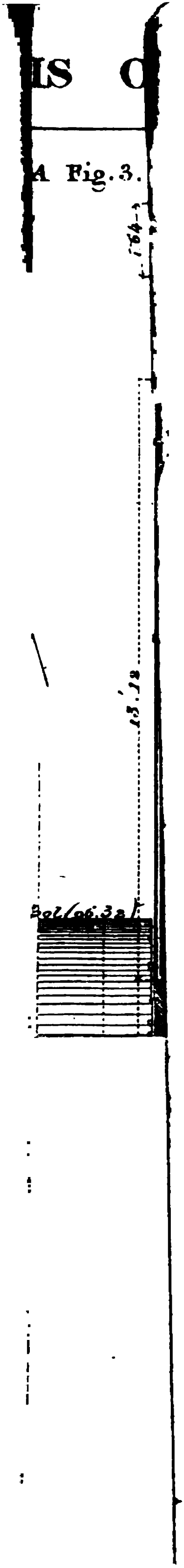
$$\frac{2596}{5391} = 0.482.$$

3d. *Gate of the lowest rank.*—The water stood at 12.47 feet in the upper pool and 6.56 feet in the lower pool above the sill or the bottom of the gate, hence the fall was 5.91 feet and the gate was completely submerged in the lower pool; hence it sustained a hydrostatic pressure of 62.5 pounds $\times 2.54 \times 5.91 \times 4.26 = 5570.33$ pounds.

The dynamometer oscillated from 2,728 to 3,212 pounds in raising the gate 3.94 feet, besides there was a shock at a certain moment which marked on the dynamometer 4,092 pounds; but I think that this figure should not be considered, because this was due to the gate encountering a bracket-place of the cross-bars of the trestle. Subtracting the weight of the gate from 3,212 pounds we find 2,948 pounds, and for the coefficient of friction

$$\frac{2948}{5570.33} = 0.532.$$

Thus in spite of the defective conditions of the experiment, in which the projections on the face of the trestles considerably increased the friction, the ratio of the forces required to move the gates to the hydrostatic pressure on them did not rise above 53 per cent. Furthermore it is impossible to deduce from them the coefficient of friction because the pressure on the gates due to the velocity of the current is altogether unknown.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A Fig.3.
1.64
13.18
302 (06.32)

SUMMARY.

To sum up, the experiments made at Port à l'Anglais have entirely confirmed our anticipations, and the dam with trestles and ordinary sliding gates realizes the following conditions:

1st. It is much more simple than the dam with movable wickets named after M. Chanoine; it will allow the pools to be raised much higher, and even to the level of the banks of the river, at a much less first cost per running foot of navigable pass.

2d. As the operation of closing only requires that the water shall be allowed to flow over a weir, with a movable apparatus for closing it, during the placing of the last gates, the linear water-way of the dam may be reduced, provided that the total section suffices for the passage of floods, and in the greater number of cases there will be found an additional saving in first cost.

3d. The maintenance will be much easier and less expensive than that of dams with movable wickets always under water.

4th. For the same height of pool the first cost will be very nearly the same as for the trestle and needle dams of M. Poirée.

5th. The pool can be raised much higher with gates than with needles, and the first cost will not increase too rapidly with the depth of the pool.

6th. The service-bridge can be raised sufficiently high above the upper pool not to be covered by an unexpected flood, and there will never be any danger of not being able to open the dam in time, no matter how long the maneuver may require.

7th. The water flowing over the entire length of the dam, as with M. Chanoine's wickets, we can do away with the long and expensive fixed weir which must accompany needle-dams, and hence we shall find a great saving in first cost, at the same time with greater security.

8th. We can always regulate, as with needles, the water-way of the dam in proportion to the discharge of the river, and we shall never be obliged to open or close the entire dam rapidly, at the risk of creating a hurtful wave or lack of water in the pools below.

9th. It will be very easy to calculate at any moment the discharge from the overflow across the crest of the dam, and to telegraph to the dam-tenders below the maneuvers that they must perform.

10th. The discharge of the water being spread uniformly over the entire breadth of the river, eddies will be less troublesome; and the same will be probably true of scours.

11th. The overflow along the entire breadth of the river will maintain in the upper pool a surface current that will carry off all the floating refuse that generally collects just above the needles of a Poirée dam.

12th. When a dam is partly or wholly open, it will not be necessary to wait to close it until the level of the river shall have come down to a given mark, to the prejudice of navigation and of factories situated on the upper pool, as is generally the case with other kinds of dams. We shall, on the contrary, be able to keep the upper pool at an invariable level without letting it fall or rise, except in time of floods, when the dam, entirely open, produces no more effect than if it did not exist.

13th. The dam will be as tight as possible during low-water, and almost the entire discharge of the river may be used for water-power.

14th. No submerged mechanism will be necessary; the hoisting-apparatus placed on the foot bridge will be always accessible and easy to keep in order, no matter how complicated it may be.

15th. However great may be the force required to raise the gates, this operation will cause no danger to the dam-tenders, even should a rope, a chain, or a part of the windlass give way, because the gates will always be in stable equilibrium and will be unable of themselves to produce any shock.

16th. The pool can be raised, if necessary, after the first construction of the dam without great difficulty or great expense, if it should become necessary.

17th. If the pool is to be raised to the level of the banks, we can regulate its water-line by experience and by trials, by gradually raising the gates to the maximum level, stopping at the instant we run any risk of submerging the low parts of the valley either directly or by filtration.

On the other hand, it seems that no objections can be made to the dam with trestles and gates except as to the length of the maneuvers, and no others have thus far been suggested to us.

But, on the one hand, there are, I think, more advantages than disadvantages in maneuvering movable dams very slowly, so as not to cause sudden changes in the regimen of the water, nor dangerous eddies and scours below.

On the other hand, we can place the foot-bridge very much above the level of the pool, and, as the water can flow over the entire length of the dam, it will never reach the bridge, and we shall always have all the time we need to open the dam. Furthermore, it will never be necessary to close it rapidly, because we might cause a scarcity below the dam, and that would do more harm than good.

If in certain special cases it became necessary to hasten the opening of the dam, it might be done either by means of escapements similar to those used with needles or sluice gates, or else by inserting either turning or even automatic valves in the gates, that are generally solid, or, finally, by perfecting the hoisting-apparatus, even should it become necessary to do it by means of a steam-engine where power and dimensions, however, would be very small.

PARIS, *August* 7, 1875.

R 4.

IMPROVEMENT OF THE MONONGAHELA RIVER.

The work of improvement on this river consists of building a stone lock and dam at Hoard's Rocks, 94 miles above Pittsburgh and 8½ miles below Morgantown. Mr. S. Petitdidier was the assistant engineer in charge until November 1, 1875, when he resigned, and was succeeded by Mr. J. E. Bell.

LOCK.

In my last annual report I stated that the contractors had failed to complete their work in time, and that they had received an extension until December 1, 1875. At that date they were again behindhand, but they had done well what they had done, and, as the lock was very nearly finished, I recommended an extension of their time until June 20, 1876, which was granted. At the latter date the lock was finally finished as far as let, the lift and mitre walls having been purposely omitted from the contract, in order that the lock might act as a sluiceway for the dam while the latter was under construction.

DAM.

My last annual report stated that work had been begun in getting out stone for the dam with the view of building it by day's labor. After this had progressed some time I found that the cost of quarrying and of boating was exceeding my estimates, and being dissatisfied with the way things were progressing, I asked and received authority to let out the work by contract. Bids were opened on the 20th of March, 1876, with the following results:

Number of bid.	Bidders.	Transporting stone, per cubic yard.	Laying cut-stone masonry, per cubic yard.	Laying quarry-face masonry, per cubic yard.	Laying rubble masonry, per cubic yard.	Laying dry-stone masonry, per cubic yard.	Earth-excavation, per cubic yard.
1	Smith & Hawkins	$1 00	$4 00	$4 00	$4 50	$2 00	$0 50
2	Friday & Strachan	80	4 75	4 25	4 20	3 20	75
3	Fred. Gwinner & Co	75	6 12	5 87½	5 00	3 75	60
4	Gaynor & O'Donnell	2 25	9 75	5 50	5 25	3 00	85
5	Clary & Niles	2 50	10 00	8 00	6 00	5 00	1 50
6	John B. Benedict	1 20	10 50	7 70	7 70	6 00	5 00
7	Fred. Atwater	1 10	11 16	9 16	8 90	7 40	50
8	McGowan, Morgan, Owens & Co	1 50	15 00	10 00	9 00	8 00	2 00

Number of bid.	Bidders.	Rock-excavation, per cubic yard.	Concrete, per cubic yard.	Carpenter, per day.	Blacksmith, per day.	Laborer, per day.	Aggregate of bid.
1	Smith & Hawkins	$2 00	$10 00	$3 50	$3 50	$2 00	$28,217 50
2	Friday & Strachan	2 50	7 00	3 50	3 75	1 75	30,169 00
3	Fred. Gwinner & Co	2 00	5 50	2 75	2 75	1 75	35,190 42
4	Gaynor & O'Donnell	2 25	7 50	2 75	3 00	1 75	41,108 00
5	Clary & Niles	4 00	6 00	3 50	3 50	2 25	54,231 50
6	John B. Benedict	5 00	10 50	4 50	3 50	2 50	57,225 30
7	Fred. Atwater	1 25	3 50	3 00	3 00	1 50	57,341 75
8	McGowan, Morgan, Owens & Co	10 00	6 00	3 00	3 00	1 50	75,199 00

It will be seen that Smith & Hawkins, the contractors for the lock, were the lowest bidders for the dam. I had some hesitation in recommending the award of the contract to them, but they gave me such assurances of their financial ability and of their earnest desire to do the work, that I concluded to take the risk, notwithstanding the slow manner in which they had worked on the lock. The contract for the dam was worded so as to authorize the engineer to take possession of the work and the contractors' plant on July 1 if, by that time, the contractors had not attained a certain rate of daily progress. They utterly failed to reach that rate or anything like it, and accordingly I took possession of the work at that date. Since that time we have been building the dam by day's labor. We have been greatly hindered by unusual high water, and it will probably be impossible to finish the dam during the present season. The best working time was in May and June, but this was frittered away by the contractors, and since then the season has been in the main unfavorable. Up to June 30 the contractors had laid 125 cubic yards of masonary of all kinds out of an estimated total of 5,900 cubic yards, and they had excavated for foundation 1,299 cubic yards of earth and rock out of an estimated total of 1,610 cubic yards.

Owing to the unexpected extension of the work to two years beyond the time originally allowed for construction, which extension was entirely due to the repeated failures of the contractors, and owing also to other causes stated below, there is a deficiency of about $20,000 in the sum required to finish this work.

Besides the longer time that it has become necessary to retain the engineering force, this deficiency is also due in part to the fact that in the course of construction it was found necessary to do some work that was not included in the original estimate. These additional and unexpected sources of expense are as follows:

Two years more of engineering	$6,000 00
Increase in excavation for lock, due to a change in location necessitated after foundation had been uncovered	9,500 00
Office building	1,000 00
Guard-wall below lock	3,500 00
Total	20,000 00

I would strongly urge the appropriation of this sum, as without it we will have to leave the lock and dam unfinished, and the only practical result of our expenditures (unless carried to completion) will be to make the river navigation much worse than before we began, and utterly impracticable at certain stages.

My last annual report contained an estimate for lock and dam No. 8, to be built at Laurel Run, below the West Virginia line, and about two miles below the mouth of Cheat River. As no appropriation was made on this estimate, I will repeat it:

Lock, with lock-keeper's house	$115,000
Dam	74,000
	189,000

As the lock must be built before the dam is begun, it will not be necessary to appropriate all of the money at one time, nor need all of the sum required for the lock be spent during the first season. I would, therefore, only recommend the following:

For completion of lock and dam No. 9 at Hoard's Rocks	$20,000
For lock at Laurel Run	60,000
Total	80,000

I would particularly request that the appropriation be made "for the improvement of the Upper Monongahela." This will be to the interest of the public service, as it will enable the surplus of either lock to be applied to the construction of the other. In any event, I would urge an appropriation sufficient to finish the lock and dam now partly built. Whatever is appropriated in excess of $20,000 can be advantageously used in getting out stone for lock No. 8, even should the appropriation be insufficient to justify the commencement of construction. My experience with contractors on the Upper Monongahela has been so unfavorable that I purpose, (if sanctioned by superior authority,) to do future work on this river by day's labor.

Money statement.

Amount available July 1, 1875	$101,286 09
Amount expended during fiscal year ending June 30, 1876	63,471 48
Amount available July 1, 1876, including $2,601.16 due on contracts, &c.	37,814 61
Amount that can be profitably expended in fiscal year ending June 30, 1878.	80,000 00

R 5.

WABASH RIVER.

Mr. F. Stein, assistant engineer, has continued in charge of the works on the Wabash during the past year.

At the opening of the fiscal year the following contracts were outstanding:

	Work.	Contractors.
1	Dam across cut-off at New Harmony	J. M. & R. B. Kerr.
2	Rock-excavation at Warwick's Ripple	M. W. Nolan.
3	Clearing Little Chain cut-off	C. M. Cole.

NEW HARMONY DAM.

This dam was designed to close the cut-off at New Harmony and thus restore to the main channel the water wasted through this side channel. The latter cannot be utilized for navigation on account of the heavy fall, which varies from 6½ to 7⅓ feet, depending on the stage of water. The greater part of this fall is found at the lower end of the cut-off, where there is a rock-bar entirely across the river, on which was once built a low mill-dam, which is now in ruins.

The length of the cut-off is 2 miles, while the distance around the island is 14 miles. By distributing this fall over this greater distance we will probably obtain a good navigation at all stages.

The season for work was unusually unfavorable, the Wabash Valley having been the scene, in August, of the highest flood ever known. At Vincennes, the river, when at its highest, was 22¾ feet above low water, at Mount Carmel 28⅓ feet, and at the Grand Chain 32½ feet. The whole of the bottom was inundated, and the river varied in width from 5 to 10 miles. Until this flood subsided no work could be done, thus leaving the contractors with a very limited season for the completion of their contracts.

Twenty-three cribs were sunk and anchored to the bed-rock, and 21 of them were filled with stone; 12 more cribs would have made the dam continuous across the cut-off, but the low-water season came to an end, and the work was necessarily left incomplete. During the winter some of the cribs were washed out and injury was done to the paving on the island bank. These injuries will be repaired at the expense of the contractors. The work will be completed before the close of 1876 unless the present season should prove particularly unfavorable.

WARWICK'S RIPPLE.

At this place the contractor put in a coffer-dam, but before he was able to get it tight enough to lay bare the rock, the river rose and work had to be abandoned. As payments were only due for rock excavated, the United States sustained no loss; nor was the navigation of the river improved. Another effort to do this work will be made during the present year.

LITTLE CHAIN.

The contractors' snag-fleet had barely commenced work at clearing this cut-off when the great August flood began, and soon compelled them to stop. The fleet lay idle at the foot of the cut-off for about 2 months, and as the river began to fall and to expose the destroyed vegetation of the bottoms, the climate, bad at best, became pestilential, and all hands, including the inspector, were stricken with chills and fever.

When the river got low enough work was resumed, and the cut-off was partly cleared out. The work was not finished to my satisfaction, but as it seemed useless to any longer keep a fleet manned by sick men, it was discharged. It is proper to add that few persons can stand the climate of the Wabash in the autumn, and this is one great difficulty in getting work done on it.

SURVEYS.

During the year the following special surveys have been made:

The Wabash River, from Marshall's Ferry to New Harmony.
The Wabash River, from Mount Carmel to Rochester.
The United States property at Grand Rapids.
The lock and dam at Grand Rapids.

A copy has also been made of the general map of the Wabash from Vincennes to its mouth, compiled from the general map of the Navigation Company, our own surveys, and county maps.

APPROPRIATION FOR 1876-'77.

The last appropriation act gave $70,000 to the Wabash. In reducing the expenditures on public rivers and harbors to $2,000,000, as ordered by the President, the Wabash was omitted, and consequently the only work that will be done will be to complete the outstanding contracts at New Harmony and at Warwick's Ripple.

ESTIMATE FOR 1877-'78.

Under these circumstances, I can only renew my estimate of last year, which was as follows:

For rebuilding Grand Rapids lock	$130,000
For engineering and contingencies	15,000
	145,000

Money statement.

Amount available July 1, 1875	$49,917 03
Amount expended during fiscal year ending June 30, 1876	15,802 15
Amount available July 1, 1876, including $271.88 due on contracts	34,114 88
Amount appropriated by act approved August 14, 1876	70,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1878	145,000 00

R 6.

SURVEYS FOR THE EXTENSION OF THE CHESAPEAKE AND OHIO CANAL.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, February 10, 1876.

GENERAL: I have the honor to submit the following report on the surveys ordered in the appropriation bills of 1874 and 1875 for the extension of the Chesapeake and Ohio Canal.

The appropriation act approved June 23, 1874, ordered surveys and estimates on "a route from the mouth of the Youghiogheny River, to continue the slackwater navigation up said river to its headwaters at the foot of the Allegheny Mountains, thence by canal to Cumberland, intersecting there the Chesapeake and Ohio Canal."

The sum allotted for this survey was insufficient to complete it; and, at the close of the field-work, the canal-line had only been located from Cumberland to a point 2 miles north of Ohio Pyle, a total distance of 80 miles, leaving unsurveyed 15 miles of canal and 25 miles of river. These facts were fully set forth in my preliminary report dated January 23, 1875, (Ex. Doc. 19, part 4, Senate, Forty-third Congress, second session,) in which I requested an additional allotment of $20,000, in order to complete the survey, to gauge the streams, and to locate and design the necessary reservoirs.

In the appropriation act approved March 3, 1875, an allotment of $10,000 was made "for completing the survey and estimates of the route from the mouth of the Youghiogheny River, to continue the slackwater navigation up said river to the headwaters at the foot of the Allegheny Mountains, thence by canal to Cumberland, intersecting there the Chesapeake and Ohio Canal."

In accordance with your orders, half of this sum was assigned to the completion of the Wills Creek line and the other half to a survey up the north branch of the Potomac, to the mouth of Savage River, there connecting with the line surveyed in 1873, and reported in my report of March 20, 1874. (Report of Chief of Engineers for 1874, part 1, p. 493.)

I was fortunate enough to again secure the services of Col. Thomas S. Sedgwick, late of the volunteer army, who had made the previous surveys. His very elaborate report and maps are herewith submitted. No pains have been spared to determine the exact quantities needed for the various necessary structures, and, after much study and examination, I have no hesitation in adopting the quantities and estimates which he has so carefully prepared.

WILLS CREEK ROUTE.

My instructions to Colonel Sedgwick were to survey the Wills Creek route for a first-class canal in all respects; and as this route was one that by its position must necessarily be competitive as a through transportation-route with that by way of the James and Kanawha Rivers, I directed him to adopt, for locks and canal trunk, the dimensions already chosen for that line; these are 120 by 20 for locks, and 70 feet for width of water-surface of trunk, the depth throughout being 7 feet. It is proper to add, that the lock in question is 10 feet longer and 2 feet wider than those now in use on the Erie Canal. It seemed quite evident that the route from Cumberland to Pittsburgh could have little claim for national aid unless it should prove practicable for a canal of the width and depth necessary for the most economical transportation. I am happy to state that I believe that such a canal is practicable on this line, although it was impossible to make the special studies for water-supply that are necessary before such a statement can be made with absolute certainty.

The trunk of the canal has been maintained at its standard width and depth throughout the whole length of the canal, except in tunnels, at aqueducts, and along the face of certain steep cliffs, where the excavation of the full width of trunk would have been onerously costly.

The chief works of special interest are the summit-tunnel, the inclined planes, the aqueducts, and the passage of "The Narrows." These will be mentioned in their order, but as an adequate supply of water is the prime necessity for a canal, it seems proper to discuss this question before giving the details of construction.

WATER-SUPPLY.

The first point to be settled is the amount of water required, after which comes the question of the source from whence it is to be obtained. The manner of determining the necessary quantity for the use of the canal is given in detail in Colonel Sedgwick's report. That portion of his report which discusses the water-supply is our joint work, and therefore it is not necessary to repeat it here. It will suffice to state that we concluded that a supply of 42 cubic feet per mile per minute should suffice for all the needs of the longitudinal slopes, except that an extra supply will be needed for that part of the canal on the eastern slope lying below Jennings's Run. Whatever additional supply is required on the western slope can readily be obtained from the Castleman River, and needs no special discussion. For the summit-level a supply of 87½ cubic feet per running foot in twenty-four hours, which is equivalent to 320.8 cubic feet per mile per minute, is needed, on the supposition of 150 lockages per day.

Owing to the exhaustion of the appropriation for the survey, it became impossible to make an exact location and plan for the summit-reservoir, and even had there been funds available, such gaugings of the streams as we might have made would not have been very useful, on account of the unusual amount of wet weather during last summer. On both of these points we are still compelled to use the data collected in 1826, but I believe that they can yet be used with safety. The reservoir-sites are still available, with slight changes, and the only point on which doubt can fairly arise is on the subject of the rain-fall. The cultivation of the mountain-tops may have slightly lessened the amount that can be gathered, but I hardly think the conditions have been sensibly changed since the first surveys were made.

In determining the allowance to be made for losses, I have followed Inspector-General Graeff, of the *Ponts et Chaussées*, whose discussion on canals, as given in his report on the Marne-Rhine Canal, is the latest and most thorough that I have been able to find. I insert several translations from his work, both because they have been the basis of the work on this survey, and also on account of their intrinsic value, and because I believe them to be unfamiliar to American engineers.

The profiles of the majority of canals show a highest level, with slopes descending on either side. This highest level is usually called the summit-level, and the slopes are designated as the longitudinal slopes, to distinguish them from the side slopes of the trunk. A longitudinal slope always ends when it strikes a summit or a bottom level; or, in other words, whenever the grade reverses, changing from ascending to descending, or *vice versa.* This distinction is important, as a reversion of grade is always necessarily accompanied by an entirely new arrangement for feed-water. It is a peculiarity of the Chesapeake and Ohio Canal (including the extension) that it has but one summit-level, no bottom-level, and but two longitudinal slopes.

A summit-level must have water enough to supply its losses by filtration, evaporation, leakage, &c., and also to fill the locks at either end whenever boats enter or leave the level. The longitudinal slopes only need water enough to supply the losses from natural causes, as the water which a boat brings with it from the summit-level will carry it throughout the whole length of the slope. An exception, however, must be made of boats that ascend a slope and return without going up to the summit-level; every such boat uses a lockful of water from the highest level which she reaches, which lockful is not replaced by her passage into the next higher level, and must, therefore, be made good in some other way. It should also be stated that the summit-level must provide for the losses from natural causes of those portions of the adjacent longitudinal slopes that lie above the nearest feeders on these slopes.

The following translation from Graeff (*Construction des Canaux et des Chemins de fer*, Paris, 1861) is believed to be the most complete report on water-supply that has yet appeared in print. It may be well to add in explanation that the Marne-Rhine Canal unites the valleys of these two rivers, and forms a water-communication between Paris and Strasbourg. All dimensions and quantities given in the original report have been transformed to correspond with the English system.

WATER-SUPPLY.—GENERAL CONSIDERATIONS.

The Vosges summit-level has, as has already been mentioned, a total length of 18.3 miles, and the Rhine slope, which begins at its lower end, has a total length of 37 miles. The Moselle slope, which joins at the upper end of the summit-level, has a total length of 34.8 miles. The two slopes of the canal, which are fed by this summit-level, are, therefore, nearly equal in length, and their total length is nearly four times that of the summit-level.

Brisson, in his preliminary project for the canal from the Marne to the Rhine, had even then a presentiment that it would be necessary to provide numerous feeders for the descending branches; but, in accordance with the ideas of his time, he was led especially to concentrate on the summit-levels the chief resources for feeding. Thus in all that part of the canal traced in the Sânon Valley, (Moselle slope,) which was to be about 25 miles long, he supposed that feeding would be accomplished by means of the Vosges summit-level,* for he only mentions incidentally a feeder from the Sânon. For the Rhine division, he admitted that the first feed-water would come from the Zorn above Lützelbourg, about two and a half miles from the summit-level; the second, from the Rohrbaëchel, near Hohfelden; that is, at 21.7 miles from the summit-level; and the third from one of the branches of the Zorn, near Brumath, or at a distance from the summit-level of 29.2 miles; which placed the feeders on the Rhine division at distances apart of 2½, 19, and 7½ miles.

From the commencement of work on the canal, in 1839, until 1847, but little attention was paid to the feeding of the Rhine slope. A plan for feeding from the Mosselbach, a tributary of the Zorn, near Dettwiller, was presented in 1847, during our former service on the canal; but the authorities in charge, with a wise reserve, refused to approve any isolated plan before a complete plan for feeding the Rhine slope had been studied. This study was undertaken in accordance with a decision of the minister of public works, dated March 8, 1848. M. Jaquiné, who was then chief engineer of the canal, admits, as a principle, that, except in case of a notable advantage in cost, feeders from tributaries must be given up, and those which may be considered necessary must be established on the Zorn itself; besides, that it is better to make a larger number of feeders and to expect less from them. This system is the least injurious to the mills on the water-course,† while at the same time it is, as M. Comoy has proved, the most convenient and the best for feeding the canal.

The examinations were made by M. Molard, M. Guerre, and ourself during the respective services which we all three had as resident engineers (*ingénieurs ordinaires*) in 1848, and from them it appeared that five feeders could be taken from the Zorn on the Rhine slope: the first at the Hoffmühl Mill; the second near the Mungelbaëchel Run, between Lützelbourg and Saverne; the third at the head-race (from the Zorn) of the La Rondelle Mill, between Saverne and Steinbourg; the fourth near the Lupstein Mill; and the fifth near the Münchmühl Mill opposite Brumath. (See the general plan, Fig. 1, Plate A.) Besides these feeders others could be taken from the Mosselbach and the Rohrbaëchel. These examinations, which were finished in 1848, were not followed up, as the appropriations for the canal were so reduced by political events that there

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*Those who wish to know in detail the resources of this summit-level will find them given in our article on the Gondrexange Pond, inserted in the *Annales des Ponts et Chaussées*, (1856.)

†This will be clearly demonstrated farther on.

was no hope of letting in water so soon. When we took charge in 1851, under the orders of Inspector-General Collignon, of the service of the third subdivision, including the Vosges summit-level and the Rhine slope, our first study had to be the plan for the complete feeding of this portion of the canal. We therefore had to re-examine this subject more closely. Let us now indicate the results of these examinations as far as concerns the Rhine slope.

FEEDERS FROM THE ZORN ON THE RHINE SLOPE.—PRINCIPLES ON WHICH THEY WERE CONSTRUCTED.—VARIOUS DETAILS.—CONSUMPTION OF WATER.

Article 1.—*General considerations.*

The Zorn, as gauged just above the Hoffmühl Mill, (see the map, Fig. 1, Plate A,) does not give less than 1,625,000 cubic feet in twenty-four hours during low water, and 4,240,000 cubic feet during average stages; besides, its discharge increases rapidly as we recede from its head springs; a little below Steinbourg it receives quite a large affluent, the Zintzel. At Brumath the Zorn gauges nearly 7,000,000 cubic feet in twenty-four hours in low water, and does not afford less than 14,000,000 cubic feet in average stages; we see at once what a supply we have for feeding.

The final examinations showed that feeders could be established at slight expense, since there was nothing to prevent so near an approach to the sources of supply as to make feeding as easy and as regular as could be desired. We mentioned above that this system of feeders at very short distances was not only advantageous as far as concerned the feeding of the canal, but also in respect to the damages caused to the mills on the stream from which the water-supplies are taken. This can easily be demonstrated.

Suppose that a certain length of a given canal can be fed by a feeder furnishing an average cube, A, of water, in twenty-four hours; let p be the cost of constructing this feeder. All the mills situated below this feeder will undergo the loss of this same volume of water, and if D represents in money the average damage that will result to each mill, and m represents the number of mills, the total damage will be m D.

Suppose, now, that instead of one feeder we make two, together discharging in twenty-four hours the same average cube, A, just supposed to be discharged under the supposition of a single feeder; suppose, besides, that between these two feeders there are n mills, and that the average damage experienced by each one of these n mills is d; the total damage for the n mills will evidently be $n\,d$, and only the $m-n$ mills situated below the second feeder will experience each one the average damage D. Moreover, let us designate by P the cost of constructing the two feeders. In order that the cost of the two systems (that of supplying by one and by two feeders) should be the same, we must evidently have the following condition between these different quantities:

$$p + m\,\mathrm{D} = \mathrm{P} + n\,d + (m - n)\,\mathrm{D}$$

whence

$$\mathrm{P} - p = n\,(\mathrm{D} - d)$$

When $\mathrm{P} - p$ is greater than $n\,(\mathrm{D} - d)$ it will be advantageous, as regards cost, to have only one feeder to feed the given length of canal. When $\mathrm{P} - p$ is smaller than $n\,(\mathrm{D} - d)$ there will, on the contrary, be an advantage in feeding the same length with two feeders. As feeding is easier and more regular in proportion to the number of feeders, it follows that we ought always to adopt the second system when it does not cause expenditures notably greater than the first. Moreover, let us remark that the more important and the closer together are the mills, the more chances there are that the system of numerous feeders, each taking but a small quantity of water, will be the more advantageous; for these feeders, being then narrow and very short, are not expensive, and the sum of the damages to the mills is the minimum, *while, if we take at the head and at once all the water that these feeders take in succession, and, so to speak, in detail, all the mills will suffer the maximum of damage.* As, on the other hand, it is almost impossible to foresee exactly the amount of indemnity to be paid to mills, and as the decision on this point is dependent on the hazards of a report by experts, we must conclude that it is always more sure and more economical in all respects, when an important water-course is in question, to make feeders close together, since the feeding of the canal gains at the same time as the manufacturing interest.

It is in accordance with these principles that the feeders of the Rhine slope have been arranged, and the decision of June 17, 1852, in regard to feeding the Vosges summit-level and the Rhine slope, made in accordance with the propositions of the project for water-supply which we prepared on the 12th of November, 1851, finally permitted the establishment on this slope of five feeders supplied by the Zorn: The first, near the Hoffmühl Mill, was to flow into the nineteenth level, (see the map, Fig. 1, Plate A;) the second, located opposite the Mungelbaächel Run, between Lützelbourg and Saverne, was to enter the twenty-seventh level; the third was to draw its supply from the race of La Rondelle Mill, which draws from the Zorn, between Saverne and Steinbourg, and was to enter the thirty-sixth level; the fourth and fifth feeders were to draw from the Zorn at the ponds of the Lupstein and the Münchmühl Mills, near Brumath, and were to empty into the forty-first and the forty-seventh levels.

The detailed plans for these feeders were prepared and immediately carried out. However, the construction of the La Rondelle feeder was postponed, so that at present there are but four feeders on the Rhine division. The feeding at La Rondelle did not seem necessary in view of the experience acquired in supplying the canal since November, 1852.

The following table shows the positions of the feeders of the Rhine slope in relation to the summit-level, and in order to make it complete, we have added those of the summit-level itself as they are to-day, together with their respective distances. This table recapitulates all the feeders constructed on the third subdivision since we had charge of it:

Names of feeding-places and points on the canal.	Abscissas of feeding-places or of points on the canal referred to the head of the summit-level, round numbers.	Distances between the feeding-places or points on the canal, round numbers.	Remarks.
	Miles.	*Miles.*	
Head of summit-level	0.0	....	
First feeding, from the Gondrexange Pond.	2.7	2.7	These three are the principal feeding-points of the Vosges summit-level.
Second feeding, from the Gondrexange Pond.	4.4	1.7	
Mouth of feeder from the Sarre	11.1	6.7	
Feeding from Wesbach Run	12.2	1.1	These three feedings are of no great importance to the summit-level, but they cost almost nothing, the streams being easily turned so as to fall into the canal, and yet they render some service; they can yield from 50,000 to 70,000 cubic feet in 24 hours in low water, and from 175,000 to 210,000 cubic feet in average stages.
Feeding from Unterzees Run, above the Arschwiller tunnel.	16.3	4.1	
Feeding from the Teigelbach at the exit from the Arschwiller tunnel.	18.1	1.8	
End of summit-level, lower end of lock No. 1.	18.3	0.2	
Feeding from the Zorn at Hoffmühl.	20.7	2.4	Enters the nineteenth level just below the ramp of lock No. 18. The abscissa is measured to the lower end of the lock where the feed-water first enters.
Feeding from the Zorn at Mungelbaechel.	25.1	4.4	Enters just below the ramps of lock No. 26. The abscissa is taken to the lower end of the lock.
Feeding from the Zorn at Lupstein.	36.6	11.5	Enters just below the ramps of lock No. 40. The abscissa is taken to the lower end of the lock.
Feeding from the Zorn at Münchmühl.	44.4	7.8	Enters just below the ramps of lock No. 46. The abscissa is taken to the lower end of the lock.
Lower end of lock No. 51	54.7	10.3	
Entrance of canal into the Ill	55.3	0.6	The Wacken channel in the river.
Total length	....	55.3	

We see that the greatest distance between two supply-points is eleven and a half miles, and that the summit-level has only to feed 2.4 miles of the Rhine division. The conditions for feeding this division of the canal are, then, very good in all respects. Consequently, it was found that, almost from the time it was opened to navigation, it had throughout its normal depth of 5½ feet.

Article 2.—Details of the feeders.—Losses.—Consumption of water.

It now remains for us to give some special details on the feeders of the Rhine slope. We need not discuss here their locations, which have been determined by study of the details of the projects, but we must give information which may be useful for other similar constructions; we sum it up in the following table; the lines of direction of the different feeders can be seen on the map. (Fig. 1, Plate A.)

Name of source of supply.	Longitudinal profile.		Cross-section.			Principal references in feet above sea-level.				Artificial constructions on feeders.
	Descent of bottom in 100 feet.	Length in feet.	Width at bottom in feet.	Slope of sides.	Width of banks in feet.	Sill at source of supply.	Water-surface at source of supply.	Sill at entrance into canal.	Water-line of canal.	
1. Hoffmühl feeder, emptying into nineteenth level below lock No. 18.	0. 0674	21 65	6. 56	2 base.. 1 perp..	4. 92	(714. 09)	(717. 37)	(712. 67)	(715. 95)	One dam on the Zorn with stop-planks having two openings each 8.2 feet wide; one opening for water at entrance of feeder 6.56 feet wide; one bridge over feeder; one aqueduct entering canal, with one weir and two supply-culverts, each having an opening of 2.46 feet.
2. Müngelbaëchel supply-station, emptying into the twenty-seventh level below the ramps of lock No. 26.	....	....	....	....	....	(642. 78)	(649. 01)	(645. 73)	(648. 03)	One dam on Zorn, and another one for regulating supply, with a valve-opening 3.28 feet wide. (The plan of this work is given on plate D, figures 33 to 37.) This supply-station has no feeder proper; water is drawn directly from the Zorn, which is contiguous to the canal.
3. Lupstein feeder, emptying into the forty-first level just below the ramps of lock No. 40.	Level. 0. 033 Level. 0. 027 Level. 0. 026 Level. Total length	83. 33 301. 10 31. 60 487. 64 10. 50 371. 71 18. 53 1, 304. 41	24. 60	3 base.. 2 perp..	3. 28	(524. 99)	(528. 53)	(524. 33)	(525. 32)	Water drawn from the race of the Lupstein Mill, siphon attached to the tail-race, and furnished with a valve of 3.94 feet opening; an aqueduct over a road; a culvert over the feeder; an entrance-aqueduct into the canal over the tow-path, with opening of 4.92 feet.
4. Münchmühl feeder, emptying into forty-seventh level just below the ramps of lock No. 46.	0. 117 0. 042 Total length.	670. 57 1, 509. 78 2, 180. 35	24. 60	3 base.. 2 perp..	3. 28	(472. 79)	(477. 51)	(472. 17)	(474. 10)	Water drawn from the race of the Münchmühl Mill by means of a gate with an opening of 4.92 feet; one waste-weir discharging into Wingersheim Run; one culvert over the feeder; one aqueduct for the passage of a road; one entrance-aqueduct into the canal under the tow-path, having an opening of 4.92 feet.

NOTE.—None of the Zorn feeders can be used for floating logs; nor can the stream itself. The Sarre feeder of the summit-level is floatable; it has a width of 9.84 feet at the bottom, a depth of from 1.64 to 2 feet, and a longitudinal slope varying from 6 inches to 1 foot per mile.

All these feeders have been constructed so as to furnish much more than is required for feeding the sections of the canal to which they belong. They are so arranged that if all the lower feeders should fail at once in consequence of accidents or repairs, each feeder can supply all that part of the canal embraced between itself and the end of the Rhine division; and, besides, so that when all the feeders are operating together, the filling of the whole Rhine division (at 237 cubic feet per running foot) can be accomplished in three days after a drainage,* in which it is supposed that the canal is entirely emptied. We will not give here the details of calculations on the construction of the feeders, as any engineer can make them without any difficulty. The considerations that control in determining the maximum discharge of a feeder are the total cube that is required for filling the part of the canal that it is designed to feed, and the minimum time that can be allowed for this filling. These are what usually determine the maximum discharge, and consequently the dimensions of the feeders. Thus, a feeder which should feed a section of canal twelve miles long, for which is required, at the rate of 237 cubic feet per running foot, a total cube of 15,016,320 cubic feet, ought to be able to discharge, if the time for filling is fixed *à priori* at three days, $\frac{15016320}{3}$, or 5,005,440 cubic feet per day. As the filling requires 237 cubic feet per running foot, and as the greatest losses per running foot and per day that can be encountered in canals apparently should not exceed 30 to 40 cubic feet, (for it is evident that when this limit is passed there can no longer be any question of feeding without enormous expense, and that it is then always more economical to commence the use of concrete in order to reduce the expenditure of water,) and as, moreover, the ordinary consumption due to losses can be but little more than 10 cubic feet in a canal in its normal state, it follows that if we establish the maximum supply from the feeders in accordance with the conditions which we have just indicated, these feeders will always afford an abundant supply. The cube for filling being 237 cubic feet per running foot, it is necessary, in order to fill in three days, that the feeders should supply per running foot and per day $\frac{237}{3}$, or 79 cubic feet. This feeder would therefore suffice for ordinary feeding, except when more than 79 cubic feet per running foot and per twenty-four hours was required.

If we had to deal with such a canal, it is evident that it would be necessary to make other arrangements for the regulation of the maximum discharge of the feeders; but we pity engineers who might have to feed it. It is undoubtedly well to establish feeders so as to be largely above the needs for feed-water, but nevertheless this principle must not be exaggerated beyond measure; for from it would result an unjustifiable increase in the cost of constructing the works connected with these feeders.

Besides the condition which we have just indicated, we think that it is well that each feeder should at least be able to feed the length of canal supplied by the feeder next below, in order to be able to dispense with a feeder in case of accidents or repairs. On the Rhine slope, as the total length from the first water-supply to the Wacken channel is only 36½ miles, the additional condition has been satisfied that each feeder should be able to feed all the canal below it. Had the division been longer and the feeders farther apart, this condition, so complete in all respects, could not have been fulfilled.

Let us fix our ideas by symbols.

Let—

$p_1, p_2, \ldots\ldots, p_n$, be the n feeders of a slope;

p_m one of the feeders between feeder p_1 and feeder p_n;

$l_1, l_2, \ldots\ldots, l_m, \ldots\ldots, l_n$, the length of canal fed by each one of these feeders;

$c_1, c_2, \ldots\ldots, c_m, \ldots\ldots, c_n$, the cubes of water consumed per running foot and per day of twenty-four hours, for the total supplying of the portion of canal to be fed by each feeder, this feeding comprising all losses of every kind, as well as the water consumed by navigation;

$d_1, d_2, \ldots\ldots, d_m, \ldots\ldots, d_n$, the daily discharges of the feeders in order to supply the necessary water;

V the volume of water needed per running foot of canal for filling after a drainage in which the canal is supposed to be entirely emptied;

K, the maximum number of days allowed for filling the canal after a drainage;

$D_1, D_2, \ldots\ldots, D_m, \ldots\ldots, D_n$, the daily supplies that the feeders should give in order to refill the canal;

We will evidently have the following relations between these different quantities:

$$d_1 = c_1\, l_1 \qquad d_2 = c_2\, l_2 \qquad d_m = c_m\, l_m \qquad d_n = c_n\, l_n \qquad (1)$$

$$D_1 = \frac{V}{K} l_1 \qquad D_2 = \frac{V}{K} l_2 \qquad D_m = \frac{V}{K} l_m \qquad D_n = \frac{V}{K} l_n \qquad (2)$$

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* It must be understood that this is in case the river can furnish water enough—that is, during ordinary stages; for in low water it would not furnish enough to fill in three days, and would require at least five or six.

In the first place, it is necessary that each feeder should satisfy the conditions ot supply indicated by equations (2.) It is also necessary that in case of necessity it should satisfy the condition of feeding, in addition to its own section, that of one or more of the succeeding feeders. If a feeder, p_m, ought to feed up to another feeder, p^1_m, it being understood that these two feeders are comprised between the feeders p_1 and p_n, this condition as to its supply is expressed by the following general equation, $\triangle_m$, representing the discharge determined in accordance with this condition:

$$\triangle_m = d_m + d_{m+1} + \cdots\cdots + d^1_{m-1}$$

Or, in view of the conditions in equations (1),

$$\triangle_m = c_m l + c_{m+1} l_{m+1} + \cdots\cdots + c^1_{m-1} l^1_{m-1} \qquad (3)$$

Moreover, in accordance with relations (2) the discharge required of this same feeder for replenishing the canal is—

$$D_m = \frac{V}{K} l_m \qquad (4)$$

In determining the maximum discharge in accordance with which a feeder should be constructed, we should choose the greater of the two values $\triangle_m$ and D_m, calculated by the two equations (3) and (4). Suppose, for example, that a feeder p_1 ought, in case of necessity, to feed, besides its own proper section, those of the two feeders following—that is, up to feeder p_4; we must then make in equations (3) and (4) $m = 1$, and $m^1 = 4$; and they will become—

$$\triangle_1 = c_1 l_1 + c_2 l_2 + c_3 l_3 \qquad (5)$$

$$D_1 = \frac{V}{K} l_1 \qquad (6)$$

Let us now suppose the following numerical values:

$c_1 = 22$ cubic feet;
$c_2 = 16$ cubic feet;
$c_3 = 19$ cubic feet;
$l_1 = 33{,}000$ feet;
$l_2 = 50{,}000$ feet;
$l_3 = 53{,}000$ feet;
$V = 237$ cubic feet;
$K = 3$ days;

Whence, by substitution in the two equations (5) and (6),

$\triangle_1 = 2{,}485{,}000$;
$D_1 = 2{,}607{,}000$.

By constructing the feeder p_1 so as to make it discharge 2,607,000 cubic feet—that is, as much as is necessary to make it fulfill the condition of replenishing—it will more than satisfy the other condition. If, instead of the numerical values given above for c_1, c_2, and c_3, we were to adopt the following:

$c_1 = 22$ cubic feet,
$c_2 = 22$ cubic feet,
$c_3 = 22$ cubic feet,

the other quantities preserving the same numerical values as in the preceding example, we would have—

$\triangle_1 = 2{,}992{,}000$ cubic feet;
$D_1 = 2{,}607{,}000$ cubic feet.

It would then be necessary, in order to continue to satisfy the condition of the occasional feeding of the feed-sections of the feeders p_1, p_2, p_3 by the feeder p_1, to construct this feeder p_1 so that it could discharge 2,992,000 cubic feet in twenty-four hours. Moreover, it is evident that we are only giving examples for calculation, and that we are not now concerning ourselves with the relation between the discharge of the feeder and that of the river whence its waters are taken. The latter question must evidently be studied on each water-course in accordance with the importance of the mills which it supplies.

Let us now give some details on the manner of determining in practice the quantities V, K, c_1, c_2, c_3, &c.

The cube V, per running foot for replenishing, varies with the cross-section of the canal; for the cross-section of the Marne-Rhine Canal it is 237 cubic feet, (22 cubic meters.) The number, K, of days that we wish to devote to replenishing the canal depends on the needs of navigation; it is generally important that it should be the smallest possible; but, on the other hand, we cannot lessen it below certain limits without causing currents prejudicial to the interior slopes of the canal. In our water-supply project of November 12, 1851, we fixed it for our calculations at three days; this is nearly what has since been found in practice when the canal was replenished after the drainages of 1853 and 1854.

The cubes c_1, c_2, c_3 of the consumption per running foot and per twenty-four hours for the full supplying of the different parts of the canal are among the most difficult things to determine *à priori*. The losses per running foot can only be determined by experience; but when a project for a canal is prepared we cannot avoid making suppositions concerning them, depending on the nature of the soil, and analogous with what have been given by soils of the same class on other canals.

Brisson supposed that the canal would lose on an average 8 cubic feet per running foot, (0.75 cubic meters per running meter;) later, 11 cubic feet (1 cubic meter per running meter) was allowed in the first studies for feeding the Vosges summit-level; but experience demonstrated that, when the more important tightenings were once completed, (and we must always suppose this to have been done, if we do not wish to obtain enormous expenditures of water,) this figure was too large. The losses since the works executed during the drainage of 1854, while we were on this service, (as was seen in chap. vii, § 12, table No. 1,) have usually been for sandy soils 3.6 cubic feet per running foot (0.30 cubic meters per running meter) in twenty-four hours, and for argillaceous soils from 4.7 cubic feet to 9.5 cubic feet per running foot (from 0.44 cubic meters to 0.88 cubic meters per running meter) in twenty-four hours. On the Central Canal, (*Canal du Centre,*) M. Comoy allows, (*Annales*, 1841:)

	Cubic feet.
For sandy soils	3. 77
For argillaceous soils	5. 27
On the Southern Canal (*Canal du Midi*) the mean cube for all argillaceous soils is	5. 60

And this is also very near the average of the losses on the Rhine slope in this kind of soil.

In an argillaceous portion of the Rhône-Rhine Canal, this cube was	4. 95
Taking the mean of the last three quantities, we get a cube of	5. 27
For sandy soils we will take a mean of our results and of those admitted by M. Comoy, which gives	3. 55
Let us with M. Comoy add to these figures 0.43 cubic feet (0.04 cubic meter per running meter) for false maneuvers, and other causes of loss independent of the losses by evaporation, absorption, and filtrations of all kinds which they represent, and we obtain for sandy soils	3. 98
And for argillaceous soils	5. 70

Which we may call, as a maximum, 4⅛ and 6½ cubic feet.

As to the concreted portions, we may count for their losses from 0.54 cubic feet (0.05 cubic meters per running meter) to 0.86 cubic feet, (0.08 cubic meters per running meter,) and adding the 0.43 cubic feet for false maneuvers and other accidental losses, from 0.97 cubic feet to 1.29 cubic feet, or, as a maximum, 1 cubic foot to 1.5 cubic feet.

The above represents the normal condition to which a canal made properly water-tight ought to come in a few years, but until then more water must be furnished, and we think that in adopting in the estimates of a preliminary project the figure for the average consumption of 11 *cubic feet per running foot in twenty-four hours,* [1 *cubic meter per running meter,*] *we will generally be on the safe side as to first necessities, and we will consequently have more resources than at a later period will be required for the ordinary supply.* To these figures of the consumption of water, which represent the average loss per running foot due to losses of all kinds, we must add the consumption of water per running foot due to the special movements between the ports situated on the slopes, to differences in capacity of the locks, and to the assemblage of boats in the short levels. The elements of the calculations to be made to determine these expenditures have been given by M. Comoy These calculations will always be somewhat hypothetical as to the first and the third of those causes of consumption of water, but nevertheless they will determine in a sufficiently approximate manner the total daily consumption of water due to the navigation comprised between two sources of supply, and by dividing it by the length we will have the consumption per running foot, which must be added to the figures which we have just given for the consumption due to losses of all kinds. The sum of these two quantities will give the quantities $c_1, c_2, c_3 \ldots\ldots$, and we will thus have all the elements necessary in order to calculate the maximum discharges of the feeders of the slopes, and consequently to determine the cross-section and the grade of the feeders, as also the discharges of the entrance valves. All this presents a chain of calculations very complicated in appearance, but which, in fact, occasion no difficulty in their details. In a preliminary project it is impossible to determine the quantities $c_1, c_2 \ldots$ exactly, since we have only hypothetical data on the consumption of water due to the navigation proper, *but we think that in adopting from* 13 *to* 16 *cubic feet per running foot in twenty-four hours* (1.20 *cubic meters to* 1.50 *cubic meters per running meter*) *for the total consumption as far as concerns the slopes, but not the summit-level, we will never be in danger of making a mistake.* For the summit-levels it is always prudent in a preliminary project to calculate everything at the maximum, both the losses and the consumption due to the passage of boats. If n designates the maximum number of boats which we suppose will pass through the summit-level, e the cube of a lockage, L the length of the summit-level, the cube of water consumed by navigation per running foot will be—

$$\frac{2\,en}{L}$$

and if c represents the cube allowed per running foot for the losses of all kinds of the summit-level, *we will have for the value of the total cube* C *consumed per running foot of the summit-level*—

$$C = c + \frac{2\,en}{L}$$

If we admit $c = 11$ cubic feet as the maximum, which appears entirely sufficient in general for the first wants of a canal whose worst portions have been made tight before water was admitted, and if in addition we assume the case of the locks of the Marne-Rhine Canal, whose average lockage is 17,658 cubic feet, (500 cubic meters,) we will have—

$$C = 11 + \frac{35316\,n}{L}$$

We will generally assume for n the maximum number of boats that can pass through a lock in a day of twelve hours, plus a part to pass through in the night. In our project for water-supply of November 12, 1851, we allowed forty-five boats in twenty-four hours.

To conclude this article, we will recapitulate in the following table everything that may be of interest as regards water-supply in the feeders of the Rhine slopes :

Names of feeders.	Lengths fed by each feeder.	Supply per feeder in 24 hours according to the project for water-supply of November 12, 1851.		Mean supply for complete feeding per 24 hours and per feeder, as determined by the experience of the canal.		Remarks.
		Calculated for replenishing in 3 days, at 78.9 cubic feet per day, and per running foot; or maximum discharge of feeders.	For the total ordinary supply between two feeders.	From September 5, 1853, to September 4, 1854; before the drainage of 1854.	From November 6, 1854, to March 5, 1855; after the drainage of 1854.	
Hoffmühl feeder	l_1=23,210 feet =4.4 miles.	*D_1=1,831,269 cub. ft.	d_1=218,639 cub. ft.	d_1=138,932 cub. ft.	d_1=56,504 cubic ft., (2.43 cubic ft. per running foot.)	The cubes of the last two columns are the means from the notes and calculations of the daily gaugings of the different feeders. The drainage of 1854 began for these portions of the canal on September 4 and terminated on October 1, 1854. The replenishing ended on November 5, and the normal feeding began on November 6. The averages for the eighteen weeks between November 6, 1854, and March 12, 1855, the day on which this was written, appear in column 6. These averages will gradually be somewhat further reduced in consequence of improvements in maintenance.
Mungelbaëchel feeder..	l_2=60,367 feet =11.43 miles.	D_2=4,762,956 cub. ft.	d_2=702,639 cub. ft.	d_2=659,907 cub. ft.	d_2=366,223 cubic ft., (6.06 cubic ft. per running foot.)	
Lupstein feeder........	l_3=41,539 feet =7.85 miles.	D_3=3,269,537 cub. ft.	d_3=379,713 cub. ft.	d_3=765,077 cub. ft.	d_3=305,339 cubic ft., (7.37 cubic ft. per running foot.)	
Münchmühl feeder.....	l_4=54,215 feet =10.27 miles.	D_4=4,277,594 cub. ft.	d_4=566,886 cub. ft.	d_4=963,304 cub. ft.	d_4=471,251 cubic ft., (8.69 cubic ft. per running foot.)	
Totals	179,231 feet =33.95 miles.	14,141,356 cub. ft.	1,867,877 cub. ft.	2,527,220 cub. ft.	1,199,317 cubic ft.	

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* The Hoffmühl feeder, having been the first one ready for trial, was made so as to discharge about 4,238,000 cubic feet in 24 hours, on the principle that each one of the feeders should, in case of need, feed all that portion of the slope below it.

This table shows, by comparison of the values of $d_1\ d_2\ d_3$ on the same line of the three columns 4, 5, and 6, that, as far as regards the daily supply, we had adopted in our project of 1851 for the water-supply sufficiently large data, which have not been reached in practice. For all the feeders of the Rhine slope the average discharges, after the drainage in 1854, have, in fact, been less than those which we calculated in our project for the water-supply.

We see that from the end of the drainage of 1853 to the beginning of that of 1854, the four feeders have never discharged in all (for losses and the navigation on the slope) more than 2,527,220 cubic feet in twenty-four hours, and as the total length fed by these feeders is 179,231 feet, (33.95 miles,) we see that the maximum value of the average water-supply per running foot in twenty-four hours has not exceeded on the Rhine slope $\frac{2527220}{179231}$, or 14.23 cubic feet, and that, after the drainage of 1854, this average consumption was $\frac{1199317}{179231}$, or 6.69 cubic feet per running foot and per day, and this result was obtained one year after the final opening of navigation on the canal.* *We therefore believe that we are warranted in saying that in admitting in a preliminary project, as we have advised above, the numbers* 13 *to* 16 *cubic feet per running foot* (1.20 *to* 1.50 *cubic meters per running meter*) *for the total maximum consumption in twenty-four hours,* (*on the slopes, including the consumption due to the harbors or basins on the slopes,*) *we will never risk running short when our resources have been calculated on these figures.*

Many canals in France have yet much room for improvement in the supply of water. This result must in a great measure be attributed to the unfortunate idea of the times in which they were built, of accumulating all resources at the summit-levels, (a fault very difficult of reparation,) and consequently underestimating the losses. At present the opposite ideas rule; they are certainly more correct; but, nevertheless, they must not be pushed too far for fear of dragging the government into expenditures out of proportion to the results to be attained. *It is, then, a proper limit to maintain, and we think it will generally be correct, to allow in a project for a canal from* 12 *to* 15 *miles as the least distance between two successive feeders, and for the total consumption of water on the slopes* (*chap.* viii, § 2, *art.* 2) *in the first trials after the admission of water, including therein the consumption due to the local movements in basins or ports, the figures of from* 13 *to* 16 *cubic feet per running foot in twenty-four hours; for the consumption due to losses the figures of from* 8 *to* 11 *cubic feet in the first months after the admission of water, and from* 4 *to* 6 *cubic feet after the canal has nearly arrived at its normal state; and, lastly, for the consumption of a summit-level per running foot and per twenty-four hours, the figures of from* 11 *cubic feet* $+\frac{2\,en}{L}$ *to* 5 *cubic feet* $+\frac{2\,en}{L}$ *according to the state of water-tightness of this level, n being the maximum number of boats assumed to pass in a day,* L *the length in feet of the summit-level, e the cube of the lockage, or the prism of lift contained in the chamber of the type of lock adopted for the projected canal.*†

We think that by balancing the expenditures and supplies of water on this basis there will be no danger of mistakes in the future, *and, if we have to deal with a portion of canal which is entirely concreted, we think from* 25 *to* 28 *miles can be permitted between feeders without inconvenience, and that we can allow for a total expenditure of water from* 4 *to* 6 *cubic feet per running foot of slope, including local navigation, and from* 1 *to* 1½ *cubic feet for the losses only; and for a concreted summit-level an expenditure equal to* 2 *cubic feet* $+\frac{2\,en}{L}$ *per running foot in twenty-four hours; but it must be thoroughly understood that these last estimates do not include the supplying of portions of slope which draw from the summit-level the water required to make good their losses.*

Article 3.—*Statement of the chief calculations relative to water-supply.*

When we know, on the one hand, the cube of water daily furnished by the feeders, and, on the other hand, the cube of water consumed by the local navigation of a slope, it is easy to deduce from these the mean daily discharge due to losses of all kinds in the section supplied by each feeder. In a summit-level this is still more simple; for it is sufficient to deduct from the total volume poured by the feeders into the level during twenty-four hours the number of lockages which have been drawn from this pool at each end, and it is the simplest thing possible to take account of the consumption due to navigation by simply counting the number of times that the locks are used. For the slopes, by keeping the same accounts at all the locks lying above the levels that have feeders, we obtain the means of calculating exactly how much navigation takes from and how much it restores to the sections corresponding to each feeder. A specimen of this calculation has already been given in article 1 of § 10 of chap. vii.

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* The discharges of the feeders, which were assumed in the preliminary project, (column 4 of the above table,) give a total cube of 1,867,877 cubic feet, which, divided by the length, 179,231 feet, gives a cube per running foot of 10.42 cubic feet, which, as can be seen, is still much greater than the actual cube in practice.

† It is evident, however, that this consumption does not embrace the supplying of those parts of the slopes which are fed by the summit-level. The consumption of these portions must be added to obtain the total consumption of the summit-level.

To make the table which recapitulates the discharges of the feeders, it is sufficient to calculate the gaugings which result from the daily notes concerning these feeders. These gaugings should be regulated by detailed instructions, in order that the agents may make them, and forward them each week, all made out, to the local engineer, who has only to verify them. In a service where there are many feeders it is impossible to do otherwise, if we wish to keep the work up to date. The formulas to be used ought always to be given for each kind of flow, with specimen calculations, in order that a person may make them without being a mathematician.

We give below the model of the recapitulative statement which we caused to be prepared every quarter in order to keep us advised of the movement of the waters of the Vosges summit-level. This statement shows on the one hand the total cubes furnished by the feeders during the three months, and, on the other hand, the cubes consumed by the canal, so that there ought to be nearly a balance between the final totals of these two series of discharges. However, we used the word *nearly*, because it is impossible to expect that the two series of operations should give results entirely identical. Here is one of the recapitulative statements whose form may be useful to persons who may have to make these calculations on water-supply:

Recapitulative statement of the feeders of the summit-level, and of the distribution of the entire water-supply of the summit-level and its two slopes, from Monday, July 2, to Monday, October 2, 1854, *(or for the third quarter of* 1854.)

Statement of the weeks, 1854.	FEEDERS.				DIVISION OF THE WATER.				Remarks.
	Gondrexange Pond.	Feeder from the Sarre.	Wesback, Unterzess, Arschwiller.	Total.	Slope of the Moselle.	Slope of the Rhine.	Losses of the summit-level and of the Sarre feeder by filtrations and soakage.	Total.	
	Cubic feet.								
July 3 to 10.......	12, 436, 860	3, 273, 546	896, 875	16, 607, 281	7, 341, 907	....	1, 977, 674	9, 322, 581	The losses of the summit-level, which is 18.3 miles long, may be calculated at very nearly 247,000 cubic feet (7,000 cubic meters) per day for this quarter, without including evaporation (summer season and before the tightenings executed during the drainage of 1854.) The losses of the Sarre feeder, which is 4.7 miles long, may be valued at 35,000 cubic feet (1,000 cubic meters) per day, not including evaporation. These losses will almost completely disappear when the side-slopes have been reworked.
July 10 to 17.......	13, 822, 213	5, 288, 549	1, 730, 218	20, 840, 980	5, 996, 063	341, 008	1, 977, 674	8, 314, 745	
July 17 to 24.......	9, 991, 705	7, 455, 094	1, 153, 737	18, 599, 536	8, 254, 144	520, 941	1, 977, 674	10, 752, 759	
July 24 to 31.......	11, 429, 476	7, 036, 565	1, 725, 521	20, 191, 562	7, 297, 585	225, 314	1, 977, 674	9, 500, 573	
July 31 to Aug. 7..	23, 439, 890	....	....	23, 439, 890	4, 133, 022	728, 667	1, 730, 465	6, 592, 154	
Aug. 7 to 14.......	30, 964, 940	672, 162	....	31, 637, 102	2, 458, 427	209, 123	1, 977, 674	4, 735, 224	
Aug. 14 to 21.......	23, 391, 940	843, 725	....	24, 235, 665	4, 010, 724	191, 093	1, 977, 674	6, 179, 491	
Aug. 21 to 28	16, 207, 540	769, 068	43, 262	17, 019, 870	6, 368, 660	51, 667	1, 977, 674	8, 398, 001	
Aug. 28 to Sept. 4..	7, 385, 874	1, 128, 263	105, 806	8, 619, 943	3, 506, 346	....	1, 130, 100	4, 636, 446	
Sept. 4 to 11	Drainage of	the canal	from Sep	tember 1.					
Sept. 11 to 18									
Sept. 18 to 25									
Sept. 25 to Oct. 2...									
					(*a*)5, 544, 553	(*a*)4, 785, 265	....	10, 329, 818	
	149, 070, 438	26, 466, 972	5, 654, 419	181, 191, 829 (*c*)1, 433, 673	54, 914, 431	7, 143, 078	16, 704, 283	78, 761, 792 (*b*)103, 219, 300	
								181, 981, 092 (*d*)915, 699	
Totals, (sensibly equal)				182, 625, 502	....	....	....	181, 065, 393	

(*a*) Expenditures due to the passage of boats through the end-locks of the summit-level. (*b*) Discharges of the waste-weirs of the summit-level. (*c*) From the notes taken at Héning the height of water evaporated between the 2d of July and the 1st of September was 5.84 inches, and that of the rain-fall 9.37 inches, whence results a difference of 3.5 inches, which must be applied to the sum of the surfaces of water in the summit-level and in the Sarre feeder, which is 4,909,829 square feet, to wit, for the summit-level 4,502,838 square feet, for the Sarre feeder 406,991 square feet, total 4,909,829 square feet. (*d*) Volume to be deducted corresponding to the lowering of the water-surface of the summit-level from reference (5.31) on July 2d to (5.02) on September 1st, the day on which the drainage began.

The calculations, and the record of actual experience, which are given in the above translation are believed to be a full justification of the figures of water-consumption which have been adopted on the extension of the Chesapeake and Ohio Canal. For more convenient reference, I have consolidated the above experience in the following table, which, it is believed, will be useful to engineers in charge of canal construction or maintenance.

WATER-SUPPLY.

Canal 48½ feet wide at water-line, 33 feet wide at bottom, and having 5¼ feet of water.

Method of construction.	Distance between feeders.	Per running foot in 24 hours.		
		Slopes.		Summit-level.
		Losses by evaporation, soakage, filtration, false maneuvers, and similar causes.	Total consumption, including the foregoing, and also losses due to local movements, differences in size of locks, crowds of boats on short levels, and navigation generally.	Total consumption, including navigation.
		In cubic feet.	*In cubic feet.*	*In cubic feet.*
Canal with earthen side-slopes.	12 to 15 miles..	8 to 11 in first months; 4 to 6 afterward.	13 to 16	*$\frac{2en}{L}$ + (from 5 to 11)
Canal tightened by concrete.	25 to 28 miles..	1 to 1½..............	4 to 6	*$\frac{2en}{L}+2$

n = maximum number of boats passing in one day; e = prism of lift; L = length of summit-level in feet.

* These figures do not include those portions of the slopes whose losses are supplied from the summit-level. Additional allowance must be made for them.

In assuming for the extension of the Chesapeake and Ohio Canal a consumption on slopes of 42 cubic feet per mile per minute, which is 11½ (more exactly 11.42) cubic feet per running foot in twenty-four hours, we have exceeded the allowance given in the third column for ordinary canals, but are somewhat under the figures given in the fourth column. The reason for this is given in Colonel Sedgwick's portion of this report, but it may be well to again call attention to the fact that the nature of the country between Cumberland and the summit-tunnel is such that it is highly improbable that there will be any considerable local navigation (navigation that does not ascend to the summit-level) above Jennings's Run, and for the slope between the latter place and Cumberland a special reservoir will be built which it is believed will supply the excess of water needed on this portion of the canal.

It is well, however, to look at the worst possible case, and see what can yet be done should we fail to obtain a sufficiency of water for a canal with earthern embankments, built in accordance with the usual methods. The second line in the foregoing table shows that a canal tightened by concrete loses only about one-fourth as much water as the ordinary type of canal. The use of concrete is undoubtedly expensive, but it is believed that in the majority of cases it is both cheaper and preferable to spending large sums on additional reservoirs. In some cases it will evidently be the only possible resort.

The following translation from Graeff's work shows how a canal should be concreted, and the results that may be expected:

METHODS OF MAKING WATER-TIGHT—TYPICAL CROSS-SECTIONS—DESCRIPTION OF THE MEANS USED—CHOICE OF THE METHOD OF TIGHTENING ACCORDING TO LOCAL CIRCUMSTANCES.

¶In the third subdivision of the canal, which was under our charge as local engineer from 1851, three methods of making water-tight were used, depending upon the degree of importance of the losses—concrete, puddling with earth, and sand. All portions that successive trials, by admitting water, had shown could not be tightened otherwise, were tightened with concrete, and the losses in such cases were generally greater than 32 cubic feet per running foot (3 cubic meters per running meter) in twenty-four hours.* Puddling with earth was used for ordinary tightening where the losses varied from 22 to 32 cubic feet per running foot (2 to 3 cubic meters per running meter) in twenty-four hours. Lastly, when the loss was not greater than 22 cubic feet per running foot in twenty-four hours, only sand and muddy water were used. The above was the usual course; but it was sometimes modified by special circumstances. When a section of the canal did not lose more than 3 cubic feet per running foot (0.30 cubic meter per running meter) in twenty-four hours, it was considered as having obtained its normal condition, and nothing more was done. When the loss did not exceed 5 cubic feet per running foot (0.50 cubic meters per running meter) in twenty-four hours, it was concluded that it would improve in tightness of itself, and if anything at all was done it was some small operations with muddy water, whenever, after the expiration of a certain time, the losses had not diminished.

To gauge the losses, and to determine their importance, ditches were dug at the feet of the outer slopes, and their contents were united in a single principal ditch, which carried them to the nearest water-course; in this ditch a small dam was made by a single plank, and the losses were gauged by the flow over this dam.

1.—*Making water-tight by concrete.*

In tightening the canal by concrete the methods and the cross-section successfully employed in the first subdivision of the canal by M. Malézieux† were used; the normal arrangements of this cross-section are indicated by Fig. 21, Plate F. The concrete revetment is 6 inches thick on the floor, and 4 inches at its upper ends on the side-slopes; it is covered by a cope (*chape*) three-fourths of an inch thick, on top of which there is a foot of earth, which necessitates an excavation below the floor of the canal of about 19 inches.

The depth of earth can be advantageously reduced from 1 foot to 8 inches; this arrangement sufficiently protects the concrete, and leaves the top of the earth-revetment at 4 inches below the normal level of the bottom.‡

In the portions where we had at our disposal fine gravel for concrete, we reduced the thickness of the concrete revetment of the bottom from the 6 inches of the normal cross-section to 4 inches, and for the upper parts of the side slopes from 4 inches to 3 inches. Now, these revetments have succeeded just as well as the others; we therefore believe that when the concrete is made of fine gravel the thickness on the bottom can be reduced to 4 inches without inconvenience, and that thus a very marked saving can be realized in the price per running foot. When broken stone is used for making concrete, the thickness of 4¾ inches seems to be the least that can be permitted on the bottom. These limits, however, only apply to cases where the earth has finished settling. When further settlement is to be apprehended, the thickness of 6 inches appears to be a minimum, and this thickness has been increased to 7 and even to 8 inches in our concrete work on the fresh earth-works of the Arschwiller descent. It may, therefore, be admitted that the limiting thickness of the bed of concrete will vary between 4 and 8 inches, according to the more or less solid nature of the soil which is to be covered. We do not mean to say that a bed of 8 inches will break any less readily than one of 4 inches if there are serious settlements; it is clear that this extra thickness will not prevent it; but with thicker beds the repair of fissures is much easier made than with thin beds, and this is, in our opinion, the sole reason for giving them the preference on new earth-works.

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* There are portions of the summit-level which lost 140 cubic feet per running foot (13 cubic meters per running meter) in twenty-four hours, according to gaugings of the apparent losses only, and in the Arschwiller descent, portions which lost from 215 to 323 cubic feet, (20 to 30 cubic meters per running meter.)

† M. Malézieux has published a very good account of these works in the *Annales des Ponts et Chaussées*, 1856. This chapter was written at that time, and we have nothing to change in it; we have only abbreviated the detailed description of construction, which would have duplicated M. Malézieux's work.

‡ As the bottoms of canals tend to rise by the deposits which are always brought in by the feed-water, it would be advantageous to keep the bottom throughout, and especially in the levels adjoining the feeders, lower than the normal level that it ought to have, in order to obtain the established draught of water; thus, for a depth of 5 feet 3 inches, as is maintained in the Marne-Rhine Canal, it would have been a good thing to have placed its bottom at 5 feet 7 inches, and even at 5 feet 11 inches, below the water-line. This excellent arrangement is only found in a portion of the former division of M. Guerre, between Wilwisheim and Strasbourg. In consequence this section of the canal has thus far avoided the dredging which it has already been necessary to do in several others.

The experiments which we made with concrete 4 inches thick, in places not liable to settle, when we had good gravel at hand, and the undoubted success of the operations, made us think that the thickness could be still further reduced, and with them the cost of the work, (which is the stumbling-block of the system of tightening by concrete,) by entirely suppressing the concrete, and only employing ordinary mortar. An experiment on a large scale would have necessitated a special authorization, and time was pressing during the drainage of 1854, when the idea occurred to us; therefore we could not have this trial made; and after the drainage of 1854 there was nothing left in our division that required concrete, so that the system in question could not succeed in getting a trial on this canal; but we nevertheless made a trial in an excavated trench 3 feet 3 inches square at bottom, which we arranged with the same inclination of side-slopes and height of banks as the canal, and, by means of what was left of the lime used during the drainage of 1854, (an unfavorable circumstance, since this lime was ten months old when we used it,) we treated this trench as follows: In the first place, all projecting stones were removed from the side-slopes, and after the earth had been sprinkled with whitewash, there was spread on it a first layer of mortar about 1½ inches thick, made with coarse sand. This layer was treated by the methods of puddling, which will be explained farther on, and on top of it was placed a cope (*chape*) of lime mortar three-fourths of an inch thick, as on ordinary concrete-work. The whole was then covered by a layer of earth one foot thick, and water was admitted to a depth 5 feet 3 inches, the depth in the canal. Now, this trench holds water as hermetically as a pot,* (excuse this phrase from the workshop.) and consequently we must believe that this new method of tightening, which costs less than half as much as ordinary concrete-work of 7 inches in thickness, including the cope, may sometimes be used. We believe that it will certainly succeed on all divisions either in excavation or embankment where final settlement has already taken place; that is to say, everywhere where there are no longer any movements to dread. Now, there are many portions of canal of this character that require tightening, and where, in consequence, we could employ this cheap method, and yet arrive at the same results as by making much more costly concrete. Lastly, it would be just the thing for tightening feeder or irrigation canals. As these kinds of canals have much less depth of water than navigation canals, it seems to us certain that the system would there succeed in every particular in the most complete manner.

On very wet divisions we build under the concrete little dry-stone channels of 8 by 8 cross-section, (half of Fig. 21, Plate F,) covered by a plank from 1¼ to 1½ inches thick, on which the concrete rests, and these little conduits of subterranean water are led to the first culvert under the canal, into which they are made to empty. In addition, when it becomes necessary, the natural surface is traversed by transverse channels of the same section as the longitudinal channels with which they connect. This method of draining has for its object to prevent the concrete from being wet when it is put in place, which is the most important matter possible where such thin layers are used.

When there are strong underpressures to fear, vent-holes with clack-valves are placed in these little channels, and thus the outside waters are permitted to enter the canal whenever their pressure is greater than that of the canal-water. This condition occurred in level No. 51, near Strasbourg, at the time of the great Rhine flood of 1852. Figures 24, 25, 26, and 27, Plate F, give the details of the vent-holes which we had placed in this level; they are placed in the bottom, and at the feet of the side slopes of the canal-trunk.

When the whole of the cross-section is not concreted, which may happen when there is a certainty that the losses do not extend over the entire width, it is necessary at the end of the concrete to make a little guard-wall, likewise of concrete, one foot deeper than the general layer, and one foot in width, in order to prevent the water from flanking this layer; this is what we did in some portions of the thirtieth and thirty-seventh levels. These partial concretings are to be recommended especially in cases where the engineer knows his ground perfectly, and where he himself did the work of constructing the canal. Moreover, the joining an old concreting to a new one is easily effected; care is taken to dress the joint with a chamfer, to wash it, and to prime it with a good layer of mortar three-fourths of an inch thick, against which the new concrete is placed and strongly rammed; care is then taken to make the new coat overlap the old one so as to perfectly cover the joint. If afterward the engineer should find that he had made a mistake in making a partial concreting, he can complete it during the next drainage; in that case there are some additional contingent expenses, and the loss of the concrete of the little guard-walls, which limit the partial section and become useless as soon as the whole section is concreted. However, we must not unreasonably exaggerate the disadvantages of this method, which succeeds, and, consequently, is a great economy when the soil is thoroughly known, and which may fail in the first instance without causing any great increase of cost in the works required to complete it; it often permits the fixed and limited amount of an appropriation to attain a first result over a greater length, which is subsequently completed by the credits of the following appropriation in those portions that are defective; but for this purpose it is necessary to be very well acquainted with the soil, under penalty of running the risk of only attaining insignificant results by this first operation.

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* Before the mortar was applied the trench rapidly lost all the water that was put into it. This mortar-work was still in existence in 1856, near lock No. 33, and the statement could be made that since this economical covering, the trench had absolutely only lost the water which evaporated.

Let us give an example of the success of a partial operation which we caused to be executed in the thirtieth level over a length of 1,180 feet. This level has the transverse profile No. 9 *bis.* (Fig. 17, Plate B.) In this 1,180 feet many large leaks were observed which made their way into the Zorn at the foot of the side slopes of the Lutzelbourg road. When the canal was emptied during the drainage of 1854, it was seen that the water was ingulfed in the excavated slope on the right hand by crevices in the slope and in the bottom. The slope on the left hand—that is, the slope in embankment—was entirely intact, and borings made in it showed that the embankment was very good. Only the slope in excavation on the right hand and the bottom were concreted, and when water was re-admitted into the canal all the cracks, without any exception, had disappeared. In another portion of this level, concreting was only done on the right-hand slope, and on 3¼ feet of the bottom at the foot of this slope, through a length of 625 feet, and this operation was just as successful as the preceding one. Therefore, there was realized in the first portion, by the arrangements adopted, an economy of 25 per cent., and in the second an economy of 70 per cent., over the cost of concreting the whole cross-section. There are, therefore, cases in which there should be no hesitation in concreting part of the cross-section. This method, wisely combined with that of concreting the whole section, will enable the use of concrete for making water-tight to become a very admissible operation as regards expense, while at the same time retaining for it an incontestable superiority over all other methods.

In those portions where the trunk was between walls, and where the bottom lost water, we caused this bottom to be concreted with layers of the same thickness as for the ordinary cross-section. Figs. 15 and 20, Plate B, show these arrangements. The thickness was increased to 7 inches in the Arschwiller descent. It is necessary to be careful, before pouring concrete against masonry, to clear the face, to wash it properly, and to dash on it a good coating of mortar, against which the concrete is placed. Without this precaution, which procures a good union, the concrete will always be separated from the masonry. In addition, a slight ridge is formed where the cope joins the wall, and this ridge is perfectly bonded into the face of the wall. In the passage through Saverne we treated in this manner a portion where the wharf-walls were founded on piles and riprap on the site of an ancient marsh. A small channel of dry stone was built against the piling under the bed of concrete, and this leads the subterranean water to a culvert, and the tightening has been a success; however, the thickness of the bed of concrete was increased to 10 inches, and even to 12 inches in some places. Fig. 15, Plate B, shows these arrangements.

The use of concrete with as small thicknesses as those which were adopted in these operations (4 to 8 inches) necessitates special precautions and methods. In the first place, it must be made of small fragments, and when broken stone is used it should not be too large to go through a ring of a diameter varying from 1½ inches to 2 inches. Suppose the concrete perfectly made, as we necessarily must, the following are, in brief, the methods used by M. Malézieux:* The concrete is first spread and then rammed until the mortar becomes fluid on the surface to a depth of about three-quarters of an inch. On the side slopes it must be laid in layers of from 6 to 8 inches in thickness, and successively raised to the top by ramming the layers. As this operation tends to make the revetment bulge, this is corrected by beating the slope of the concrete with a flat beetle. This second operation completes the first, and makes the mortar perfectly fluid on the surface. Moreover, our experience has proved that in cases where but a slight thickness is used, we can omit ramming the slopes in layers, and that the flat beetle is sufficient. We can also use on the bottom layer, in order to complete the effect of ramming, a light beetle made of a piece of plank 12 inches square. By means of a vertical handle light blows are given to the concrete until fluid-mortar makes its appearance on the surface. When the concrete has been rammed and no stone remains on the surface, it is beaten with the *sarate.* It is well known that General Haxo was the first to use this method. The *sarate* used by M. Malézieux, and also used without change by us on our works, is a round piece of leather, doubled, from 12 to 16 inches in diameter, mounted with a handle. This leather is stuck full of heavy nails very close together, like the sole of a miner's shoe. It weighs from 6 to 9 pounds. After the first beating, and when the concrete begins to get stiff, it is once more beaten with a heavier *savate*. M. Malézieux took 22 pounds as the weight of his, and it is better that it should be heavier rather than lighter. Such a *savate* is made of leather four double. After this last work the concrete is permitted to lose its water, and to settle, and then it is beaten with the *savate* a second time, and a third when necessary; but it is seldom necessary to use the *savate* more than twice. In our opinion the delicate part of this use of the *savate* is the interval of time which must be left between this operation and that of ramming which precedes it and prepares for it. This interval is very variable. It is a matter of judgment and knowledge of the materials employed, which in this case is the trick of the trade. In order that savatting may succeed, it is necessary that the concrete should neither be too moist nor too dry. In the first case savatting will not amount to much. In the second it is rather hurtful than useful. It is excellent when the right moment is seized. There is therefore need of men and plant prepared for this work, which is delicate, but which produces very satisfactory results when it is well managed. After the concrete is thus prepared the cope (*chape*) is spread over it. The latter ought to be made of excellent mortar tempered very stiff. In our works we had at our disposal hydraulic lias limes which set in from eight to ten days. The cope was usually spread on the concrete from thirty to forty hours after the last savatting. To make it adhere well it is necessary, as M. Malézieux advises, to clean the surface of the concrete with care by means of small brooms, and to sprinkle it, if the latter is necessary on account of atmospheric conditions. The cope is rammed with a light beetle when it begins to harden. After this ramming it is savatted two or three times, and finally smoothed with a trowel. This series of operations, perfectly laid out by M. Malézieux, renders it so tight that in portions well made not a drop of water is lost. It is necessary, however, to take care to shelter it from the sun during warm weather. With this view it is covered with matting between operations. When it is finished and there is no more danger of cracks, it is covered with earth from which the stones have been carefully extracted. The cracks are effaced, when there are any, by the use of a *savate* and a trowel.

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* For further details see the article by M. Malézieux, *Annales des Ponts et Chaussées*, 1856.

There only remains for us to speak of the repairs of fractures in concretings when the latter are made on embankments which have not entirely finished settling. The following is the method which has been successful with us: The fracture is enlarged for a depth of 1½ or 2 inches, so as to give it from three-quarters of an inch to an inch and a quarter in width at the bottom, and this joint is filled with Vassey cement. When the fractures are quite large it is necessary to employ other methods, which we will have occasion to indicate when we speak of the admission of water into the Arschwiller descent, where this case occurred under the most complicated circumstances that could be encountered in this kind of work.

There now remain for us some details on the organization of the work-yards, and under this head we will only point out the practical results of the works which we have had to direct. In the first place, the following are the cubes of mortar and of concrete which form a running foot of concrete-work, as given by the average results of all the concrete-work executed in the third subdivision. (We will not speak of earth-work, which can easily be calculated from the cross-section, and which is always done by the job.)

It is necessary to count, per running foot, for the normal cross-section (Fig. 21, Plate F) wholly concreted, an average cube of concrete of from 21½ to 30 cubic feet, according as we adopt 4 or 6 inches of mean thickness on the bottom; for a cross-section between walls having 39 feet 4 inches of average width on the bottom, we must count on from 20 to 25 cubic feet per running foot, including in this the little ridges against the walls, according as we give a mean thickness of 6 or 8 inches to the bottom. It is also necessary, in the normal profile for full concreting, to have an average per running foot of 4.3 cubic feet of mortar and 2.7 cubic feet in the cross-section between walls. Finally, if an engineer should find himself, on account of local circumstances, in the necessity of employing the economical method of tightening by mortar, he will need, for a thickness of 1½ inches, a cube of coarse mortar of 8.6 cubic feet for the first layer, and for the cope, of three-fourths of an inch in thickness, 4.3 cubic feet of common mortar, which would make a total of 12.9 cubic feet per running foot for the normal cross-section.

Knowing the composition of the mortar, and of the concrete, it is easy, after what has just been said about the relative cube for each kind of cross-section, to calculate the provisions necessary for getting a work-yard ready. In our works the copes were made of mortar composed of lime and sand; the lime came from the liassic limestone of Hochfelden and Zenacker; these limes set in eight days on an average when they are well slaked. The proportions determined for a cubic yard of mortar were 0.45 cubic yard of lime slaked into a stiff paste, and 0.90 cubic yard of sand, or the proportion of 1 to 2.

A cubic yard of concrete was composed of 0.55 cubic yard of mortar, and 0.82 cubic yard of gravel or broken stone, or the proportion of 2 to 3. When the gravel is not entirely free from sand it is advisable to adopt for concrete the proportion of 3 of mortar to 4 of gravel. For broken stone, the proportion of 2 to 3 seems to be that which should be preferred. These data, in addition to that of the swelling of the lime, which must be determined by experiment in each locality, enable ready calculations to be made of the provisions requisite for a concrete-yard for concreting a given length with a given cross-section.

When long lengths are to be treated, it is advantageous to procure rails and cars for transporting mortar from the mortar-mills to the place where it is to be used; but this plant is too costly where small yards are used. Mortar can readily be transported in a cart from the mortar-mill to the place where it is to be used. But when this vehicle is used the mortar-mills should be brought nearer, so as to reduce the length of transport. We think that unless we have to make a total length of five to six miles, it is advantageous to use carts, and, consequently, not to buy a plant of rails and cars, which always loses much of its value when we wish to sell it. In our concretings in the department of Bas-Rhin, and on the summit-level, iron tracks were used, which mostly came from the department of the Meuse, where the works were finished. In the Arschwiller descent the mortar was carried in carts. In making mortar, we used the mortar-mill exclusively, mortar made by this machine being in our opinion much superior to that obtained by any other process.

A horse-mill generally made from 1.57 to 1.70 cubic yards of mortar per hour, and a two-horse mill from 2.50 to 2.60 cubic yards. Knowing the cubes of mortar required per running foot for the concrete and the cope, cubes readily calculated from the data given above, we generally determine the least number of mills to be put up according to the length of concreting to be done, and the time available for finishing it, for this is almost always the starting-point, as the operations in question are generally carried on during the drainages, and consequently in a limited and generally very short time.

In 1852 we did our concreting at Government expense by the day. In 1853 we began to do it by the job, and that of 1854 was all done by the latter method, in which there was the advantage of great simplicity in the accountability, while at the same time the work was done more economically, and with all desirable perfection, when there were good inspectors to oversee the work, and this is a fundamental and *sine quâ non* condition. In concretings by the job which were done under our direction the following payments were made by the piece: For a cubic yard of mortar, 34 cents; for a cubic yard of concrete, 44 cents; and for a square yard of cope, 2½ cents.

In the estimates that accompany this report no note is taken of the cost of concreting or mortaring any portion of the canal. The reason for this omission is that it is impossible to tell how much of this kind of work may become necessary, as it is entirely dependent on the condition in which the canal is found to be after water is admitted. I have introduced this subject, however, in order to show, by the experience of other countries, that there need be no doubt of the practicability of extending the Chesapeake and Ohio Canal to Pittsburgh, no matter how much the water-supply may have been lessened since 1826.

I believe that the calculations presented in this report show that the canal is practicable, even if made with unprotected earthen banks; therefore, *à fortiori*, it must be practicable if we tighten it with concrete.

SUMMIT-TUNNEL.

The summit-tunnel, as located by the surveys of 1826, was placed at a height above low-tide of 1,972 feet. The tunnel now proposed is placed at a height of 1,944 feet above tide, or 28 feet lower. This lowering of the summit-level is advantageous in suppressing twice that amount of lockage; but the chief reason for the lowering was a desire to bring the summit-reservoir nearer to the canal, and to dispense with the long feeder of the old project.

The length of the tunnel, as now proposed, is three and three-fourths miles, as against a length of four miles for the old tunnel. This decrease in length, notwithstanding the adoption of a lower level, is due to the greater depth to which the open cuts are carried.

The profiles show that the proposed height of tunnel is 28 feet, and the proposed width is 46 feet. These dimensions are larger than those of any railroad or canal tunnel of which I have been able to learn, but I believe that large dimensions are justified if all the conditions are fully considered. It is decidedly my opinion that if the tunnel is not built so as to permit continuous traffic in both directions, its utility will be so greatly impaired as to make its construction, and therefore the construction of the canal, unadvisable. The resistances to navigation are greatly increased where the boat area is nearly equal to the canal area, and if the tunnel does not permit the simultaneous passage of boats going in opposite directions, the daily tonnage on the canal will be greatly reduced. There is a tunnel now in operation on the finished portion of the Chesapeake and Ohio Canal which fully illustrates both propositions. This tunnel was built to cut off the Paw-paw bend of the Potomac, and is 3,118 feet in length, with solid tow-path and only enough water-way for one boat. Consequently boats cannot pass in the tunnel, navigation can take place in only one direction at a time, the traction and the labor of the animals are greatly increased by the smallness of the water-way, and the speed of transit is greatly reduced. Having passed through this tunnel during last summer, I can speak from personal experience.

The following statement of President Gordon, in his annual report of 1870 to the stockholders of the Chesapeake and Ohio Canal, is of interest in this connection:

> The tunnel is about five-eighths of a mile in length, and only wide enough for one boat to pass through it, and as all the coal-boats have to pass this point, the loaded boats and the return boats have to wait upon each other, and very considerable delay is thus produced. The capacity of the canal to carry coal consequently depends upon the number of boats that can pass through the tunnel; and it has been estimated that its greatest capacity does not exceed 1,000,000 of tons descending freight per annum in its present condition.
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> Therefore, if the canal is expected to accommodate the trade beyond that amount, as it will soon be called upon to do, provision must be made to enlarge the capacity of the canal, either by increasing the width of the tunnel so as to enable the return boats to pass the loaded boats on their way through it, or slackwater must be made along the river around the tunnel to enable the light boats to return by that passage and leave the tunnel entirely free for loaded boats. Another mode still has been suggested, which I think worthy of consideration, which is, to take the tow-path out of the tunnel and thereby enlarge the water-line, and relieve the boats to that extent from the heavy pressure of water against the bow of the boat, now produced by the narrow channel, and then draw the boats through each way by a stationary engine; the boats to be towed in fleets of five or six, by an endless band or rope attached to the engine, and which could be used to tow both ways by reversing the engine. The mules could easily be carried on the boats while passing through the tunnel.

As this matter of the proper size of the tunnel is of great practical importance, I have deemed it advisable, in this connection, to quote the experience in France in working the Riqueval tunnel on the Saint Quentin Canal, which connects Paris with Belgium, and is likewise a canal whose chief traffic is the transportation of coal.

The summit-level of this canal is thirteen miles long, and in this distance are two tunnels, of which the Riqueval is 18,601 feet (3½ miles) in length, and the Tronquoy is 3,605 feet (⅔ of a mile) in length. The distance between the tunnels is about four miles.

The tunnels are 26 feet 3 inches in width, and they originally contained two tow-paths, each 4½ feet wide, partly built solid and partly supported on arches. The original width of water-way was 17 feet, which is the width of the locks on the canal. The line was opened in 1810, and at that time the towing through the tunnels was done by manual labor. Owing to the narrowness of two dams in the fortifications of Valenciennes and Condé, through which boats had to pass, their width was restricted to 14 feet 5 inches. The water-ways in the tunnels were therefore 2 feet 7 inches wider than the boats.

To pass through the tunnels, boats were formed into fleets, and the time of passing through the long tunnel was from seven to eight hours.

The construction, in 1847, of a competing railroad, made it necessary to increase the capacity of the Saint Quentin Canal, and accordingly the passages in the military dams were made as wide as the tunnel, and the depth of water throughout the canal was increased from 5 feet 5 inches to 6½ feet. This increase in width and capacity of boats operated very disadvantageously in the tunnels, and navigation became almost impossible. The following translation from an article by M. Lermoyez, in the *Annales des Ponts et Chaussées* for 1863, fully explains the difficulties of working these tunnels:

> The nature of the work obliges boats to navigate in fleets or convoys, because they cannot pass each other, not only in the tunnels, but also in the narrow portions of the trunk between them. Consequently, when a fleet entered the tunnel it formed a long piston and drove the water before it, as the flow along the sides was insufficient, since a space of only 8 inches was left between the sides of the boats and the walls of the tow-paths. The wave thus driven forward by the fleet, spread in the level, and advanced rapidly until it met an obstacle which compelled it to retrace its steps; it then came back, re-entered the tunnel, where it caused a current opposed to the course of the fleet, stopped the boats, and created a resistance that the haulers were unable to overcome. The latter, when the wave came, instead of exhausting themselves in useless efforts to overcome it, contented themselves with preventing their boats from going backward, and only resumed their march after an equilibrium had been established.
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> This movement of the waters caused an appreciable lowering of the water-surface at the end of the fleet, and formed a veritable incline which the boats were compelled to ascend. The difference of level, which was nearly half an inch per boat, became so great for long fleets that the last boat of the convoy had not sufficient water to float it, and became stranded on the bottom of the canal.
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> It is, therefore, easy to understand how slow and laborious was the method of traction, and nothing but the attraction of large wages could prevent the haulers from abandoning their calling.
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> However, when the draught of boats was increased to 6 feet, and when this increase in draught was accompanied by an increase in width which added 25 per cent. to the tonnage of each boat, the difficulties of traction increased to such a degree that hauling by manual labor became physically impossible. The passage, which, before this change in the boats, took place in seven or eight hours, soon demanded sixteen or eighteen hours. Little by little the men, worn out with fatigue, refused to continue hauling, and the promise of wages of three francs per day could not induce them to continue an occupation which was beyond their strength.

The first effort to improve the traction was to employ a steam tow-boat, but the nature of the soil through which the Riqueval tunnel passes makes it necessary to keep the tunnel closed by gates during the winter season, and the vitiation of the atmosphere by the smoke of the engine became an insuperable objection. Towing by horses was next tried, but the duration of the passage through the three and one-half miles of the long tunnel was fourteen hours, and even with picked teams and drivers it was found impossible to reduce this time below thirteen hours, which was evidently entirely too long.

The next trial was of a horse-power tow-boat hauling on lines attached to hooks firmly fastened in the sides of the tunnel and placed at intervals of 650 feet. As fast as one line was wound in by the capstan, a new line was attached, which had previously been fastened to the hook next beyond by two men who preceded the tow-boat in a skiff for this purpose. By this means one tow-boat could tow from 30 to 40 boats, but the time occupied was from ten to twelve hours.

While this system was in operation one of the tow-paths was removed, and the increase in water-way thus created greatly reduced the difficulty of towing.

Finally, the hooks and short lines were replaced by a submerged cable, and this is the system now in use. The tow-boat tows as many as 40 boats at a time, and the average duration of the passage is six hours and fifty-four minutes for ascending fleets, and five hours and twelve minutes for descending ones.

It is evident from the above that it is of the utmost importance for the future of the canal that the summit-tunnel should be made of the maximum possible size, and that, if possible, navigation through the tunnel should be just as unembarrassed as anywhere else on the canal. If boats are compelled to wait at either end of the tunnel until a fleet is formed and the tow-boat is ready, the average time of through passages will be appreciably increased, and with it the cost of transportation. This method of working will also increase the consumption of water for lockage by increasing the proportion of boats going in the same direction during a given time.

For locks 20 feet wide we may assume that the widest boat will be 19 feet 6 inches. Two such boats will occupy a space of 39 feet, and with 3 feet for margins, a total width of 42 feet is required for convenient passage. In view of the fact that even with this width the tunnel will be the widest of any long tunnel that has ever been built, I would recommend that the clear width proposed by Colonel Sedgwick (46 feet) be reduced 4 feet, which will reduce the height 2 feet, and effect a saving in excavation of about 113,000 cubic yards, which at $4 per yard amounts to $452,000. There would also be some saving in arch-masonry and in concrete flooring.

The cost of each item of tunnel-work has been carefully elaborated by Colonel Sedgwick on the basis of present contract prices. I think that they are low, and that he hardly allows a sufficient margin for unforeseen contingencies, such as the encounter in the tunnel of a large body of water. To provide more fully for these items, while I would reduce the width of the tunnel to 42 feet, I would retain the estimate for the 46-foot tunnel. I have therefore made no change in the estimate on the summit-tunnel as prepared by Colonel Sedgwick.

It will, of course, be understood that the tunnel in question must be operated by some power other than animal strength, as no tow-path will be provided. The present tendency on all canals is so strongly in favor of steam as the motive power, that we will apparently have to wait but a short time for the entire disuse of towing by animals.

As a matter of interest I append the dimensions of several well-known and long tunnels:

Name.	Kind.	Length in miles.	Width in feet.	Height in feet.	Remarks.
Grand Junction Summit, England	Canal.....	1.16	16½	18	
Kilsby, England	Railroad ..	1.36	27	23½	
Westheath, England	Canal.....	1.53	18¼	18	7′ 6″ water.
Hauenstein, Switzerland	Railroad ..	1.55	26	24½	
Harecastle, England	Canal.....	1.66	14	16	
Netherton, England...............	Canal.....	1.73	27	24½	
Blisworth, England	Canal.....	1.75	16½	18	
Box, England	Railroad ..	1.80	30	28	
Pouilly, France	Canal.....	2.07	20½	22	
Thames and Medway, England...	Canal.....	2.25	30	34	8′ water.
Thames and Severn, England	Canal.....	2.39	15	....	
Nerthe, France...................	Railroad ..	2.88	26¼	26½	
Woodhead, England...............	Railroad ..	3.00	14¼	20	
Marsden, England................	Canal	3.15	9	17	8′ water.
Riqueval, France.................	Canal.....	3.52	26¼	26½	
Hoosac, United States............	Railroad ..	4.74	26	26	
Mont Cenis	Railroad ..	7.59	26¼	22	
St. Gothard	Railroad ..	8.97	28¼	21½	Unfinished.
Chesapeake and Ohio Summit....	Canal.....	3.75	46	28	As proposed by T. S. S.
Chesapeake and Ohio Summit....	Canal.....	3.75	42	26	As proposed by W.E. M.

The above table shows that while the proposed Chesapeake and Ohio Canal tunnel is not extraordinary in its length, being but a quarter of a mile longer than the Riqueval tunnel, it yet greatly exceeds any of those named in its cross-section.

INCLINED PLANES AND LOCKS.

The steepness of the longitudinal slopes of the canal and the local difficulties in Will's Creek Valley and elsewhere, make it unadvisable to build a canal which shall be limited to locks as the only means of overcoming differences of level. While the use of locks throughout the line is theoretically admissible, it is practically inadmissible on account of the great difficulty of keeping up the short levels between the locks, and also on account of the great loss of time in passing so many locks. For this reason a large number of inclined planes have been introduced on the line. Between Cumberland and the summit-tunnel are seventeen inclined planes, varying in height from 20 to 120 feet, and overcoming a total height of 1,185 feet. If this elevation were gained by locks with the usual lift of 8 feet, it would have necessitated 148 locks in addition to those already on the line.

In the upper part of Will's Creek the descent from the summitt is effected entirely by planes, the first block appearing 2 miles above Bridgeport.

On the western slope, which is much more gradual than the eastern, there are six inclined planes, varying in height from 36 to 82 feet, and fifty-six locks, varying in lift from 6 to 16 feet, but the majority have heavy lifts, only twelve having lifts less than 12 feet.

Of the entire practicability of these inclined planes there can be no reasonable doubt. They are in use in the United States on the Morris and Essex Canal, and in England on the Monkland Canal. Full drawings of the Morris and Essex inclined planes accompany this report. The Monkland inclined plane carries up a caisson in which the boat is water-borne. This is by far the best arrangement for the boat, but requires the strongest plane and the heaviest rolling-stock. Such a plane with caisson is now in process of construction on this very canal, about one mile above Georgetown, in order to lower canal-boats into the river, a vertical fall of 36 feet. In a few months all doubts as to its practical operation will be fully solved.

From a late inspection of this work, and after consultation with its builder, I find that the cost of the necessary machinery for this plane is $60,000, the total cost of the plane being about $100,000. As it is built on a system which, though more costly, is evidently preferable to that in use on the Morris and Essex Canal, I have thought it prudent to assume its adoption on this extension. For this reason I have doubled the estimated cost of inclined planes, and therefore add $1,134,000 to the estimates, this being the sum of the costs of the planes as given in Colonel Sedgwick's report. It is proper to add in explanation that his report antedates the construction of the plane in question, and therefore he did not have the benefit of this experience, and owing to reasons which are elsewhere stated at length, he was compelled to use estimates for planes with boat-carriages, while recommending for adoption planes with caissons.

AQUEDUCT BRIDGES.

On the eastern slope of the canal are five aqueduct-bridges, one over Savage Run and four over Will's Creek. These crossings of Will's

Creek are forced by the extremely rugged nature of the defile and the presence of the Connellsville Railroad which often prevents the adoption of a more favorable line. Designs for all of these aqueducts have been prepared. They are to be arched-masonry bridges, the span of each arch being 50 feet. The total number of arches in these aqueducts is twelve, which is a little more than an average of two arches to each aqueduct.

On the western slope are six aqueduct-bridges, of which the three over the Castleman are short, but the three over the Youghiogheny are long. Designs have only been prepared for the aqueduct-bridges above and below Falls City. The upper of these has seven spans and the lower three. There will be no difficulty in building any of these aqueduct-bridges.

PASSAGE OF THE "NARROWS."

The narrowest place through which a passage must be found for the canal is just above Cumberland. Here the space between the two halves of Will's Mountain is occupied by two lines of railroad on one bank and the National Road on the other. The manner in which Colonel Sedgwick has solved this troublesome problem is very creditable to his engineering skill. It consists substantially in widening the stream as far as possible, sustaining the sides by vertical walls of masonry, and then placing the canal in the bed and isolating it from Will's Creek by a strong masonry division-wall. The most difficult point was how to get it into the "Narrows" at the upper end without interfering with the numerous railroad tracks or with the National Road. The method adopted cannot readily be explained without maps, and to these reference is made for full information.

EXTENSION BEYOND CONNELLSVILLE.

Thinking that it would be practicable to establish a slackwater navigation on the Youghiogheny as far up as Connellsville, and knowing the strong desire of the inhabitants to have such a navigation, I directed Colonel Sedgwick to stop the canal survey at Connellsville, and beyond that place to survey the river to a connection at West Newton with the work done in 1873 by Lieutenant Mahan, Engineers. This was done, and the results are given in the accompanying maps.

Between the suspension bridge at Connellsville and the bridge at West Newton, a distance of 26½ miles, the fall of the river surface is 122.6 feet. As a rule, there is a narrow strip of bottom-land on one side and an abrupt hill on the other throughout this distance; there are a few points on the line where the construction of either slackwater or canal would be troublesome, but there is no place that compares in difficulty with points above. The worst section is in the Narrows, below Connellsville. Here we have the Little Falls, 8½ miles below Connellsville, Middle Chute, 10 miles below, and Great Falls, 11½ miles below. If a slackwater navigation is established, one dam will come at the head of Little Falls, one at the foot of the Middle Chute, and one in the rapids above Great Falls. The last-named site is objectionable on account of the narrow bed of the river at this place, but the others are good.

In estimating the cost of a system of locks and dams, the first question to be settled is the size of the locks. To determine this we must first consider the interests that require water-transportation.

Along the entire length of the Youghiogheny, from its mouth to Connellsville, there are heavy deposits of bituminous coal, and Connellsville itself is the center of a district widely known for its excellent gas-coal, coke, and iron. These products are in great demand both East and West, and their only outlets are by the Pittsburgh and Connellsville Railroad, and by a branch of the Pennsylvania Central which has been built within the past year. The producers are therefore unanimous in their desire to have cheap water-transportation both East and West. Canal-boats will answer their purpose for communicating with eastern markets, but as a large portion of the West can best be reached by way of the Ohio River, they naturally desire either to have Connellsville made the head of steamboat navigation, or else to have such a water-connection with the Ohio as will enable them to load their products at their mines into such barges as are used on the Ohio for transporting coal and coke in fleets. These barges are from 125 to 130 feet long and 25 feet wide, and it is evident that any navigation that will pass these will also pass the boats that ply on a canal whose locks are 120 by 20. If, therefore, we can arrange matters satisfactorily for Ohio River coal-barges, we will have ample space for the regular canal navigation.

Coal-barges may be brought to Connellsville through river-locks large enough to accommodate a tow-boat with one or more barges, or through river-locks accommodating only one barge at a time, or through an independent canal.

The first method I believe to be impracticable without the construction of reservoirs to furnish additional supplies in long and dry summers. For further information on this point I would respectfully refer to the report of the survey of the Youghiogheny River below West Newton, made under my direction in 1873 by Lieutenant Mahan, Engineers. It will be found in Report of Chief of Engineers for 1874, part 1, page 558. We are therefore reduced to the consideration of slackwater with locks for one barge at a time, or an independent canal with locks of the same size.

It would not be difficult to decide this question if we could tell with any certainty whether or not steam would ultimately come into general use for propelling canal-boats. If such should be the case within a few years, then slackwater below Connellsville would be by far the best construction; boats that still used animal power could be accommodated by a tow-path on one or both banks; this, however, would necessitate dredging at the heads of pools, as there is always less water near shore than in the channel, and boats drawn by lines must past near the shore.

Were there no probability of the adoption of steam for propulsion, then it would be betttr to continue the canal to West Newton, up to which point it seems practicable to have navigation with large locks.

Believing as I do that it is but a question of a few years before steam will be in general use on all first-class canals, especially on those whose chief business is the transportation of coal, I conclude that slackwater below Connellsville, with locks for barges, is better than an independent canal. Should future business justify it, there would be no difficulty in having two locks at each dam, one of which might be as large as the largest on the Monongahela; in that case such regulations could be established as would limit navigation to the small lock during those seasons of the year when there was a scarcity of water.

It is not likely that Ohio River coal-barges will ever have independent propelling power, but they could be moved up and down the river by tugs adapted in size to the locks. The only difference would be that the tug and the barge could not pass the dam at the same time.

In this respect the slackwater would be no worse than an independent canal, supposing that the barges were similarly towed on the canal.

The greatest disadvantage of the independent canal below Connellsville is that it only accommodates one bank of the river. Factories could probably transport their products to the canal by means of bridges and wire tram-ways, but the expense of such structures would operate to shut out all mines and quarries, as their heavy products must be moved cheaply in order to pay a fair return on the capital invested. An exception would be found where deep natural pools permitted boats to lock down into the pool, but such pools are too rare on the Youghiogheny to affect the general argument.

Locks to pass an Ohio River coal-barge 130 by 25 should be 146 feet between gates and 26 feet wide. These are the locks on which the estimate has been made. It is proper to state that when Colonel Sedgwick and I talked over the question of the extension beyond Connellsville we were both agreed that it ought to be a canal. The careful study of the subject necessary to prepare this report has caused me to change my mind as indicated above.

The canal-survey stopped just above Connellsville, at the mouth of Dunbar Creek. In adjusting the sites and lifts of the dams on the Youghiogheny, I found that the lowness of the bridges and the height of the floods made it difficult to establish a satisfactory connection between canal and river navigation. I finally concluded that the best way to pass the bridges without raising them, which I desired to avoid, was to continue the canal through New Haven, the town opposite Connellsville, and terminate it in the Youghiogheny just above the abandoned Southwest Pennsylvania Railroad bridge. By carrying the canal through with a water-line at the reference 868.00 we can keep above the river floods, avoid the suspension bridge entirely, and secure adequate head-room under the bridge of the Fayette County Railroad. At the end of the canal we have a lock whose lift varies from 11 feet to nothing, by means of which there will be easy exit from or entrance into the canal at all stages of the river. The local business of Connellsville will be accommodated by a basin in New Haven. It is a part of this plan to change the mouth of Dunbar Creek and turn it into the river above lock 56.

I am not at all sure that it would not be a preferable solution to remove the suspension bridge, rebuild it at a higher level, and increase the height of the first dam below Connellsville. The chief objection to this arrangement is that the surface of the Youghiogheny at Connellsville would have to be raised so high, in order to get 7 feet at the mouth of Dunbar Creek, that there would be great danger of flooding the lower part of the town in times of freshets.

The comparison of the two methods may very properly be left until such time as there seems a reasonable chance that the work may be built. For the purpose of an estimate, I have adopted the first-named plan. As the canal-survey stopped at Dunbar Creek, the estimate on this additional mile and a quarter of canal must be considered as only a rough approximation.

The estimate made by Colonel Sedgwick will, therefore, be increased by two 9½-foot locks, one 11-foot lock, and by a mile and a quarter of new canal, together with the additional embankment required from the last lock at the Fayette County Railroad bridge to the present mouth of Dunbar Creek. It will be diminished by the removal of one 16-foot lock no longer required. We must therefore modify his estimates as follows:

Additional canal trunk and increased embankments at end of old line	$35, 000
Two 9½-foot locks, at $27,000	54, 000
One 11-foot lock	30, 000
Total cost of new work	119, 000
Deduct one 16-foot lock	43, 755
Net increase in cost	75, 245

The water-surface of the canal at its new termination will be at the reference 868.00, and that of the river at the same place during low water will be 857. This, therefore, is the level of the upper Youghiogheny pool, and from it we will descend by locks averaging 10 feet until the Monongahela is reached at McKeesport, whence there is a slackwater system already in operation to Pittsburgh.

The following dams must be built:

Number.	Location.	Width of river in feet.	Lift of dam in feet.	Elevation of surface of pool above low tide.
1	One-half mile above Bradford Station	320	9	857. 00
2	Near Bradford Station	600	10	848. 00
3	One mile below Dawson	460	10	838. 00
4	Head of Little Falls	400	10	828. 00
5	Foot of Middle Chute	330	10. 5	817. 50
6	Head of Great Falls	270	10	807. 50
7	Near Layton Station	450	10	797. 50
8	Mile and a quarter below Layton	440	10	787. 50
9	Jacob's Creek Station	590	10	777. 50
10	Smith's Mills	570	10	767. 50
11	Above Snyder's Station	500	10	757. 50
12	Below West Newton Bridge	500	10	747. 50
13	Half mile below Sutersville	450	10	737. 50
14	Above Robbin's Station	520	10	727. 50
15	Long Run Station	490	10	717. 50

The last three dams, which come below West Newton, are described in my report on the Youghiogheny River, dated August 14, 1874. It is proper to state that in that report these dams were expected to maintain, at the heads of their respective pools, a depth of 6 feet, while in the present report this depth must be 7 feet in order to conform to the standard depth of the canal. This increase of one foot over the depth assumed in the report just mentioned has necessitated a change in the sites originally selected. I have also reduced the estimated cost by omitting portions of the foundation which additional investigation has shown to be unnecessary. The first twelve dams will have small locks (146 by 26) and the last three will have large ones, (250 by 56.) The great scarcity of water, which calls for the greatest practicable tightness of dam, and the slight difference in first cost and great difference in durability between a masonry and a wooden dam, have caused me to estimate only for masonry dams. The lack of time and of funds prevented an exact determination of the sites for locks and dams, and therefore we will assume that half of the upper dams and locks will be on rock and all the rest on gravel.

ESTIMATE—YOUGHIOGHENY SLACKWATER.

6 small locks on rock, at $35,500	$213, 000
6 small locks on gravel, at $40,000	240, 000
3 large locks on gravel, at $90,000	270, 000

2,180 linear feet of masonry dam on rock, at $62	$135,160
4,236 linear feet of masonry dam on gravel, at $80	338,880
6 abutments on rock, at $3,500	21,000
9 abutments on gravel, at $4,000	46,000
Total	1,254,040

In taking the sum of the lengths of the dams it has been assumed that half the widths of the locks would be in the bank, and that the lengths of the dams would consequently be less than the widths of the river by half the widths of the locks.

SUMMIT-RESERVOIRS.

As has been several times stated, no estimate was made on summit reservoirs, but an approximate estimate is required in order to make this report complete as far as possible under existing circumstances. As is stated in detail in Colonel Sedgwick's report, it is assumed that the Pleucher reservoir, proposed in the report of 1826, will be built, and also a lower reservoir nearer the line of the canal, the total capacity of the two reservoirs being 252,667,000 cubic feet.

In the absence of any better means of getting at the cost of these reservoirs, I have thought it best to follow the precedent of the new storage reservoir of the Croton aqueduct at Boyd's Corners, New York, on which an excellent report has been made to the American Society of Civil Engineers, by J. J. R. Croes, resident engineer. The capacity of this reservoir is 364,000,000 cubic feet, or 44 per cent. greater than the sum of the two reservoirs required for the canal. It has a water-surface of 279 acres, a maximum depth of 57 feet, a mean depth of 30 feet, and its total cost (omitting some additions to the original plan whose cost is not reported) was $590,000.

The dam is of masonry, and the reasons assigned by the engineer for preferring masonry to earth are as follows:

> No dam at this place could be made safe or water-tight without removing all the natural material and founding the structure on the rock. All the earth within a mile of the dam-site contained so large a proportion of bowlders and coarse gravel as to render it unfit for water-tight embankment, except at enormous expense for separating and screening out the stone. An earthen embankment would have demanded for safety a tunnel through the rock of the hill-sides for the discharge-pipe at the stream-level, and a rock-cut of some 15,000 cubic yards in the hill-side at flow-line for waste-water.
>
> The stream was liable to sudden and severe freshets, which could not be prevented from overflowing the dam during construction. Such a freshet would necessarily destroy a partially-completed earth-embankment.
>
> An abundant quantity of stone of excellent quality lay on the hill-side within a short distance of the dam-site.
>
> These considerations led to the decision that the dam should be of masonry.

I think that substantially the same reasoning, especially as regards freshets, should lead us also to adopt masonry-walls for our reservoirs. I make no estimate for feeders, as the upper reservoir will feed into the lower through the existing stream, and the lower will be so near the line of the canal as to make the cost of its feeder too small to be worth considering in an approximate estimate of this character.

I would therefore assume for the approximate cost of the two reservoirs $600,000. As the canal reservoirs are located where the country-rock belongs to the carboniferous strata, and is comparatively easy to work, the cost of masonry will be much less than at Boyd's Corners, where the country-rock was gneiss. I have, however, made no reduction on this account, believing that it would be better to consider this as an offset to the probable greater length of dam required.

SUMMARY OF ESTIMATES.

Summing up the estimates already found, we have as follows: for the total cost of a first-class canal from Cumberland, Md., to Connellsville, Pa., and of a system of locks and dams on the Youghiogheny from the latter place to McKeesport, on the Monongahela, whence to Pittsburgh there is a slackwater system in actual operation:

Canal proper, as per Colonel Sedgwick	$21,176,795
Additional cost of new terminus at Connellsville	75,245
Summit-reservoirs, approximately	600,000
Additional cost of inclined planes	1,134,000
Total estimated cost of canal	22,986,040
Estimated cost of slackwater on Youghiogheny	1,254,040
Total cost of the water-route from Cumberland to Pittsburgh	24,240,080
Which, in round numbers, may be put at	25,000,000

In conclusion, I must state that if the dimensions of this line had been restricted to those on the existing canal, the estimates would have been materially reduced. I have, however, estimated for a canal larger than the Erie, for reasons given in the opening of this report, and on the supposition that, if this extension were made, the canal below Cumberland would be correspondingly enlarged.

NORTH BRANCH ROUTE.

This route is for a canal up the valley of the North Branch of the Potomac to the mouth of Savage River. At this point it connects with the survey made in 1873 for a canal-route up this stream to the valley of the Castleman, near Salisbury. As a through route for connecting the Chesapeake with the Ohio River, the line by the North Branch of Potomac and Savage River is greatly inferior to the Wills Creek route in being longer, in having a higher summit-level, (thus necessitating greater lockage,) and in having a tunnel at least one mile longer. If, therefore, a through line is built, I am decidedly of the opinion that it should go by way of Wills Creek. For further comparison see my report, dated March 20, 1874, printed in Report of Chief of Engineers for 1874, part 1, page 493.

As a local line the North Branch route is well worth consideration, since, at the mouth of George's Creek, it reaches the great George's Creek coal-basin, from which both railroad and canal draw their supplies of coal. An extension of the canal to George's Creek would save twenty-eight miles of railroad-transportation, and would undoubtedly give the canal a business that would pay a fair interest on the cost of construction. The section of this line between George's Creek and Savage River, a distance of nearly two miles, is very difficult to construct, on account of existing bridges and mills, and the occupancy of the limited area of level ground by the town of Piedmont. There is no present need of this piece of canal, and, therefore, I would recommend that the canal-line be stopped at the nearest point to the mouth of George's Creek at which a convenient coal-basin can be built. The island, just below Piedmont, is well adapted to this use if the left channel is closed by an embankment.

On this North Branch line there are no aqueduct-bridges, no tunnels, and no inclined planes; nor need there be any doubt as to the water-supply if the canal-trunk is made reasonably tight. In case of necessity, a reservoir can be built on Savage River, or on the North Branch, that will fully make good any deficiency in dry summers.

The question has arisen whether it would not be better to build a lock and dam at the head of the present Cumberland pool, and thus have a longer length of slackwater at the lower end of this branch canal. On this point I cannot speak positively, as it would require a more definite knowledge of the low-water discharge of the stream, the height of floods, and the local characteristics of the proposed site than we were able to acquire. My present opinion is that the natural banks are so low that we would be compelled to make a low dam in order to avoid expensive leveeing against floods, and that it would not back up sufficiently far to justify its construction. Moreover, more water is needed for a slackwater than for a canal, and judging by the low state of the Cumberland pool in dry summers, I should consider it hazardous to build a dam higher up, which will only be supplied by one of the two streams that fill the Cumberland pool.

This North Branch canal has been treated as a local extension to the coal-fields of the existing Chesapeake and Ohio Canal, and therefore its dimensions and draught have been made the same as those of the canal already built. It is, therefore, a smaller canal than the one projected as the Will's Creek through-transportation route.

From the mouth of Savage River to the guard-lock at Cumberland the distance by the canal-line is 30½ miles, and of this distance nearly 2 miles is the slackwater of the Cumberland pool, leaving 28½ miles of canal proper. The fall is 335.3 feet, and is overcome by 43 locks, the average lockage being 7.8 feet. The canal is assumed to be of the same size as the Cumberland division of the existing canal, namely, 62 feet width of water-surface, 32 feet width of floor, and 6 feet depth of water, with locks 100 feet long and 15 feet wide.

The estimated cost is	$2, 656, 558
If we omit the upper two miles, whose estimated cost is	418, 314
We have as the cost of the canal from Cumberland to George's Creek	2, 238, 244

ADDITIONAL SURVEYS NEEDED.

To complete this subject, the following surveys should be made:

Survey of summit water-shed and reservoirs.

Relocation of line in the upper part of Will's Creek Valley.

Survey for an extension across Maryland to Chesapeake Bay.

The first-named might be left until work on the canal is actually begun, as I think there can be no serious question as to the practicability of supplying the canal with water, and the work on the summit-tunnel would necessarily consume so much time that the reservoirs could be surveyed and built before the tunnel was ready.

The second survey might also be left until the work of construction is about to begin. It is not absolutely essential, as the present surveys have given a practicable line of canal; still, it is desirable to make the lifts of the inclined planes more regular, and this part of the line is so complicated that additional study will be sure to repay its cost in improving the location.

The third survey I consider as very important. The canal greatly needs a connection with Baltimore or Annapolis, that will pass loaded canal-boats without breaking bulk. If the Chesapeake and Ohio Canal is deserving of being considered as one of the great through-transportation routes, it merits help in finding a better eastern terminus than Georgetown.

Dr. William Howard, in 1827, reported a feasible route from Georgetown, via the Eastern Branch of the Potomac, to Baltimore, following closely the present line of the Baltimore and Ohio Railroad.

Messrs. Fisk and Hughes, in 1837, reported to the governor of Maryland on this route, and Mr. Isaac Trimble, in the same year, made a similar report to the mayor and city council of Baltimore.

Col. J. J. Abert, Chief of the Corps of Topographical Engineers, in 1838 reported to the governor of Maryland a feasible route to connect the canal with Baltimore by way of Seneca Creek, the headwaters of Rock Creek, and Brookville. His investigations were strictly limited to routes lying wholly in Maryland, and therefore did not discuss the route via Eastern Branch.

All of these surveys and reports came to naught after the construction of the Baltimore and Ohio Railroad, but they have again become valuable on account of the national demand for cheap water-transportation.

I think that the time has now come for re-opening this forgotten question, to see if these or other routes are practicable and to decide which is the best.

I estimate the cost of this survey at $15,000. It will be more expensive than the usual survey of such a length of canal-line, because the great question will be that of water-supply by reservoirs and feeders, and this branch of the examination will require a thorough survey of the water-sheds lying above the line of the canal, as we know from past investigations that an extension to the Chesapeake is impracticable without reservoirs.

Respectfully submitted.

WM. E. MERRILL,
Major Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

REPORT OF MR. THOMAS S. SEDGWICK, ASSISTANT ENGINEER.

CUMBERLAND, MD., *December* 1, 1875.

SIR: I have the honor to make the following report of the surveys, made in 1874 and 1875, in regard to the extension of the Chesapeake and Ohio Canal, westward from Cumberland, Md. The survey commenced in 1874, and completed in 1875, was by way of the valley of Will's Creek to the summit of the Alleghany Mountains near Meyersdale, Pa., (formerly Meyer's Mills,) and thence by the valleys of the Castleman and Youghiogheny Rivers to West Newton, Pa. The other survey was made in 1875, and extended from Cumberland, Md., up the North Branch of the Potomac, to the mouth of the Savage River.

WILL'S CREEK ROUTE.

That portion of this route from Cumberland to the mouth of the Castleman River at Confluence, Pa., (formerly Turkey Foot,) has long been known as the Will's Creek route, and was surveyed in 1824 by Capt. William G. McNeill, of the Topographical Engineers, under the direction of the Board of Engineers for Internal Improvements, organized in April, 1824. The object of the survey was to compare this route with the Deep Creek route, which followed up the North Branch of the Potomac, Savage River, and Crabtree Creek, crossing the summit of the mountains by various lines, and entering the Youghiogheny Valley either by Deep Creek or by the Little Youghiogheny; thence following down the Youghiogheny to an intersection with the Will's Creek route at Turkey Foot, now Confluence.

This comparison showed the Will's Creek route to be 18 miles shorter and 440 feet lower at the summit than the Deep Creek route, and the water-supply quite as abundant.

As stated in my report of January 30, 1874, the pre-eminent advantages of this route were beyond doubt, nor would there now be any question in regard thereto, but for the fact that the Pittsburgh and Connellsville Railroad has since been constructed directly along this route all the way from Cumberland to Confluence, occupying, except near Confluence, the exact location, mile for mile, made for the canal in 1824; the same statement is true for that portion of the route from Confluence to Pittsburgh. In consequence of the railroad location the line of the canal would have to be laid on the opposite or left side of the Castleman River, except for a distance of about five and a half miles east of Confluence, and it would likewise have to be placed on the left bank of the Youghiogheny River, from Confluence to Connellsville, excepting at Ohio Pyle Falls; moreover, on that portion of the route from Cumberland to the summit of the mountains, the establishment of the railroad has introduced new conditions, so that grave doubts arose as to the practicability of laying a canal along this section at all, at a feasible cost. To determine the character of these conditions and the increased cost arising therefrom, and to determine further the cost of the whole line of canal to some point on the Youghiogheny (near Connellsville) which might be reached by slackwater, the surveys of the past two seasons have been made.

CONDUCT OF THE SURVEY.

Your instructions for beginning the survey were received on the 7th of August, 1874, but owing to the delay in making arrangements with professional gentlemen to take charge of the three surveying parties that were directed to be put into the field during the season of 1874, the two parties assigned to the divisions extending east and west from the summit of the mountains did not rendezvous at Meyersdale until the 20th of August, and, owing to some delay in the arrival of tents, they did not get to work until the 25th of August. The party assigned to the first division, that from Meyersdale to Cumberland, began operations with energy, made a traverse of the route across the mountain between Meyersdale and the mouth of Bowman's Run, and then traced the straight line connecting the points selected for the ends of the tunnel; this tunnel-line was found to agree quite nearly with the surveys of 1824 for the same summit tunnel. The party assigned to the second division, that from Meyersdale to Confluence, began work on the 26th of August, following down Castleman River. The third party, assigned to the division from Confluence to Connellsville, assembled at Confluence, and began work on the 1st of September, following down the Youghiogheny River by its left bank.

The party of the first division prosecuted their work with diligence, and completed the survey of the division to Cumberland by the 28th of November. The party on the second division had reached Pinkerton Station (Pittsburgh and Connellsville Railroad) on the 28th day of October; and on the same day the third party had pitched camp at Indian Creek, a station on the Pittsburgh and Connellsville Railroad, but their survey was 7 miles behind, extending only 2 miles west of Ohio Pyle Falls.

In accordance with the project of the survey, the three parties were to be in the field three months, but it appearing that neither of them would be able to complete the survey of its division within the allotted time, I arranged, with your consent, to disband the party on the second division, and to allot its unexpired time to the other parties; this change enabled the party on the first division to complete their survey to Cumberland. The party on the third division was directed to complete the surveys on the second division, with a view to make the whole survey complete from Cumberland to Ohio Pyle Falls, (Falls City.) The result verified my expectations, as the party on the first division reached Cumberland on the 28th of November, and the other party reached Confluence about the 5th of December, although in consequence of a heavy snow-storm they did not fully complete the survey to that place until the 10th of December, but a majority of the party was dismissed on the 30th of November.

The difficulties encountered on the survey were many and troublesome. Nearly the whole route from Meyersdale to Ohio Pyle Falls lay through an unbroken woods, with a dense and heavy growth of laurel, through which the line of the survey had to be cut day by day and mile by mile, as was the case also on the first division as far east as Bridgeport. As soon as the field-work was closed, the parties were disbanded, and headquarters established at Cumberland, for the completion of the maps, profiles, and plans.

The office-work occupied the months of December, 1874, January, February, and a portion of March, 1875, during which time were prepared fourteen sheets of maps of the line surveyed, on a scale of 1 inch to 1,000 feet; twenty-one sheets of profiles on the horizontal scale of 1 inch to 500 feet, and vertical scale of 1 inch to 25 feet, and twenty drawings of aqueducts, bridges, &c., several of the latter, however, being incomplete.

The profile-sheets show the longitudinal profile of the line as surveyed, and the positions of the locks on the line; and transverse profiles of the ground taken at frequent intervals, which illustrate the general character of the work to be done in forming the canal. The general declivity of the adjacent stream is shown by a broken line under the surface profile, with elevations and rate of fall per mile written thereon.

Where the canal can be formed by a single embankment by taking advantage of the slope of an opposing hill or mountain, the surface of the ground on which the embankment is to be built is shown by a dotted line. Sketches of the railroad bridge to be passed under at Cook's Mills, at the head of the Narrows of Will's Creek, and street bridges over Will's Creek in Cumberland, are shown, with many other details.

The maps show the general topography of the line of survey, with very accurate details of the features of the adjacent creek and rivers, and of the Pittsburgh and Connellsville Railroad. The elevations of the streams are written in their appropriate places on the maps, from which the declivity of the water-courses may be found without referring to the profile.

Information of an appropriation for the completion of the survey having been received, the report of operations in 1874 was not completed. On the 1st of April, 1875, office-work was resumed, and on the 14th of June the party organized for the completion of the survey rendezvouzed on the Youghiogheny, at Ohio Pyle Falls, in Fayette County, Pennsylvania, and prosecuted the survey for the canal-extension to Connellsville, Pa, which place, 17 miles distant from Ohio Pyle Falls, was reached on the 20th of July.

The section from Ohio Pyle Falls to Connellsville was very difficult to survey, being extremely rough and along steep mountain-slopes, covered with rocks, and with a dense growth of laurel reaching down to the edge of the river, and the party had to cross the river twice each day in a frail boat built for that purpose at Ohio Pyle.

The weather was very unfavorable for work, as during twenty days of the month employed on this section of the line of survey there was rain-fall, usually quite heavy.

From Connellsville the Youghiogheny River was surveyed with a view to improvement by slackwater as far as West Newton, a distance of 25½ miles, the survey terminating on the 13th of August. The river was carefully traced by a line surveyed on the left bank, triangulations being made to the opposite side, and numerous soundings taken on these lines of triangulations. A heavy rise in the river on the 8th of July interfered with the progress of the work for several days, and in consequenee of the high water the survey from Layton Station to West Newton had to be conducted on the right bank of the river.

The levels were connected with the bench-mark made by Lieut. F. A. Mahan, Corps of Engineers, in 1873, on the east abutment of the bridge crossing the river at West Newton, and described by him as bench-mark No. 1, with the reference, 248.157. The reference of this bench-mark in our figures is 763.71, as referred to the datum-line of the old surveys of the canal.

In my report of the reconnaissance of the Savage River route in 1873, I made mention of an old bench-mark pointed out as made in 1828, the reference of which was marked on the bench itself 1972, the datum-line as shown by the old reports being low-tide at Georgetown, D. C. This bench-mark and reference was taken as the base for the surveys of 1874, and when these surveys were brought down to Cumberland, it was found that the reference of the bottom of the canal at the feeding-lock, as thus determined, differed but 1.35 feet from its elevation, as determined during the construction of the canal. The levels of the survey on the western slope of the mountains were continued from Ohio Pyle Falls to West Newton, and they gave as the reference of Lieutenant Mahan's bench-mark the figures recorded above.

A measurably complete location of the line of the proposed canal has been made from Cumberland, Md., to the mouth of Dunbar Creek, 1 mile above Connellsville. Special attention has been given to its alignment, the crossing of streams and rivers, the location and position of locks and planes, and their lifts and heights, the selection of sites for dams to turn the available feed-water of contiguous rivers and creeks into the canal under the most favorable conditions, and to the location of basins, road-crossings, aqueducts, culverts, and other masonry structures.

The study of the application of inclined planes to the canal, as substitutes for locks, as described in my supplemental report of March 30, 1874, has been made a special feature of the survey, especially in the section from the summit of the mountain to Cook's Mills, 10 miles north of Cumberland, and locations of inclined planes have been made on that section, and several also on the descent of the western slope of the mountains.

The general character of the survey has been for a canal of the first-class, having a width at the water-surface of 70 feet, and a depth of 7 feet, with locks 120 feet long, and 20 feet wide. This size of lock will pass boats carrying 180 tons, and themselves weighing about 94 tons. These dimensions of the canal prism have been varied wherever the local conditions indicated such changes to be desirable or necessary. Aqueducts have been designed for a clear width of 45 feet; at deep rock-cuttings, and on steep side-hill slopes, where to construct a canal of the standard dimensions would be onerously expensive, the canal width has been reduced to 45 feet; a similar reduction in width is made where the canal is spanned by permanent bridges. This width will allow two boats to pass each other at the restricted places, which I consider an essential feature in a first-class canal, more particularly in view of the probable early use of steam on such canals. At all the narrow places indicated above, the sides of the water-prism will be nearly perpendicular, and the sectional area will be from 305 to 308 square feet, a loss of about 24 per cent. as compared with the full section in earth, with slopes of one on one and a half. The restricted places would have a width 2.37 times the width of the boat, and a sectional area 2.67 times the cross-section of a boat. The total length of such restricted places is not greater than judicious economy seems to warrant.

GENERAL FEATURES OF THE ROUTE AND OF THE SURVEY.

The summit tunnel is located at the same place, and on the same line selected by the surveys of 1824, the design at that time being to take the feed-water from a large reservoir to be provided on Castleman River at Forney's (now Livengood's) Mill, about 1 mile below Salisbury, Pa. The length of this feeder would have been 5½ miles.

In the report of the surveys made in 1873, on the Savage River route, I stated that the reservoir at Livengood's Mill would now be impracticable on account of the valuable property, public and private, that would be submerged thereby, and the consideration of the great loss of water that would take place on a feeder 5½ miles long led me to assume a summit-level 28 feet lower than that adopted by the surveys of 1825. By this arrangement of the summit-level the feed-water of Castleman River can be taken at a point less than one-half of a mile from the western basin of the summit-level and where a storage reservoir of a large capacity can be made.

The elevation of the bottom of the tunnel was taken 10 feet higher than the mouth of Flaugherty Creek, and its elevation above tide at Georgetown, D. C., is therefore 1,944 feet. The line for the tunnel was carefully surveyed and its length was found to be 3¾ miles, the tunnel being 46 feet in clear width and 28 feet in clear height. The cut at the western approach is 6,800 feet in length, and that at the eastern approach 1,450 feet. A basin 1,300 feet long is provided, in the village of Meyersdale, just beyond the western approach; it is formed by an embankment on the left made from the waste material from the approach cut and a natural bank on the right; at the eastern approach a basin of the same size is to be excavated. The total length of the summit-level is 5.88 miles.

Following the line of survey westward, the canal turns to the right out of the valley of Flaugherty Creek, through the town of Meyersdale into the valley of Castleman River, lying between the Pittsburgh and Connellsville Railroad and the river, on the edge of the river-bank. It continues in this position for a distance of 1.75 miles, and in this section there are two locks of 6 feet lift each. Provision is made for feeding the canal from Castleman River just below the second lock; the conditions being favorable for a dam 18 feet high, which would form a reservoir of considerable capacity.

Beyond this the canal lies at the foot of a bluff hill, around which it turns to the right, being formed by the tow-path embankment, and then turning to the left crosses the river at 2.37 miles from Meyersdale, the aqueduct being 250 feet long. Immediately after the crossing of the river the canal for a distance of 900 feet is formed by the tow-path bank on the right and a natural hillside on the left. From this crossing of the river, until within 5.4 miles of Confluence, the canal-line lies on the left bank of the river. The general character of the valley is alternately flat bottom-lands and steep side-hill slopes coming down to the edge of the river; but the flat ground is greatly in excess, and the conditions generally favorable to economy of construction. The line is often laid close along the bank of the river at the foot of steep, rocky slopes, and frequently requires to be supported by a retaining-wall founded on the rocky bed of the river. Three inclined planes have been located on this portion of the line; one of 54 feet height at 2¼ miles below Garrett Station, (Pittsburgh and Connellsville Railroad;) one of 38 feet height just opposite Castleman Station, and one just below Pinkerton of 36 feet height. The number of locks on this section is 22, with lifts ranging from 8 to 16 feet. The lifts are made to increase gradually as the line progresses down stream, which arrangement seems to be warranted by the increase in the supply available from the river for feeding the canal.

From the crossing of the river near the Brooke Tunnel, on the Pittsburgh and Connellsville Railroad, by an aqueduct 180 feet long, to the crossing of the river just above Confluence, there are five locks, and one plane of 40 feet height, the latter being at Harnedsville. The average length of the levels is 1.07 miles; the shortest levels are three in succession, of 2,000 feet each, while the longest one is 4.07 miles long.

Between Meyersdale and Confluence the canal is fed from the river at three places, at about equal distances, by dams to be built across the river with heights of from 16 to 18 feet, forming reservoir pools. One of these pools will be within 1¾ miles of Meyersdale, another at Mineral Point, some 10 miles farther on, and the third near Fort Hill.

There are no large streams coming in on the left side of the river, and only about two or three that will require a culvert so large as 20 feet span. Between Pinkerton Station, on the Pittsburgh and Connellsville Railroad, and Confluence the river is very crooked. The Pinkerton Bend is nearly 2 miles long, measured by the left bank of the river. The distance across the bend is 2,500 feet, but this route would necessitate two aqueducts and the construction of a tunnel some 800 or 900 feet long. There was not sufficient time at our disposal to survey this alternative line.

The canal-line is planned to cross the Castleman just above the town of Confluence, by an aqueduct 330 feet long, to the tongue of land lying between the Castleman and Youghiogheny, so that it may afterward cross the Youghiogheny just above the mouth of the Castleman by an aqueduct 400 feet long. These two aqueducts, 3,000 feet apart, are on the same level.

The distance from Meyersdale to the mouth of the Castleman is 32.9 miles, and the fall of the Castleman in that distance is 616 feet, which is an average of 19.3 feet per mile.

After crossing the Youghiogheny, as just described, the line is laid along the left bank to Ohio Pyle Falls, a distance of 11 miles, in which distance the river falls 106 feet. The general features of this section are very similar to those between Meyersdale and Confluence. There are eight locks, aggregating 108 feet of lockage. One and a quarter miles below Confluence there are four locks, having intervals of 2,000 feet, followed by a level 3.94 miles long. Each of the remaining levels is more than one mile long. The canal is fed from the river at a point 2.38 miles below Confluence, where there is an excellent site for a dam.

At Ohio Pyle Falls the river makes a great horseshoe bend, which is 1.9 miles long, as measured along the left bank, while the distance across the neck of the bend is but 1,800 feet, or but a few feet more than one-third of a mile. In this distance the river falls 94.7 feet.

The canal-line crosses the river at the upper end of the bend by an aqueduct 420 feet long, and the neck is passed by a cut 16 feet deep at the highest point. The descent to the river on the other side is made by a plane 80 feet in height, and the line immediately recrosses the river by an aqueduct 210 feet long at a height of 28 feet above the surface of the river. A feeder is provided to empty into the canal just below the foot of the plane, from a dam to be built about one mile above, on the bend of the river.

There are but few places between Confluence and Ohio Pyle Falls where the conditions require the narrowing of the canal below the standard width, although there are several places where the canal-line lies on steep, rocky slopes, and occasionally the bluffs come down to the river and force the line to the water's edge. In these cases retaining-walls are proposed to support the canal. Rock excavation obtains on nearly the whole length of this section, as there is but a limited amount of bottom-land, and there will consequently be some difficulty in procuring sufficient clay for puddling purposes. The Castleman and Youghiogheny Rivers both flow in rock-beds, and nearly all the retaining-walls, locks, culverts, and aqueducts can be founded on bed rock; and at nearly all the places where the canal-line is laid close on the river-bank, there are low, alluvial lands on the opposite side of the river in which new channels for the river may be cheaply made, furnishing at the same time clay for tightening and puddling the canal-banks. Rock will be so greatly in excess, that the retaining-walls may be laid up with exterior slopes varying at pleasure from 4 on 1 to 1 on 1, and of any required thickness, at the cost of laying the stones in place. The same remark is applicable to slope and protection walls.

From Ohio Pyle the line continues along the left bank of the river to the mouth of Dunbar Creek, one mile above Connellsville, at which point the survey for the canal ended. This section is 15¾ miles long and has eight locks of 16 feet lift, one of 14 feet, one of 13 feet, two of 12 feet, and one of 10 feet, and one plane of 70 feet height, opposite Stewarton Station, on the Pittsburgh and Connellsville Railroad. The lockage of this section aggregates 273 feet, and in this distance the river falls 247 feet. The level preceding the plane is 1.68 miles long, another is 2.27 miles long, and the remainder vary in length from six-tenths to one and three-tenths miles. The canal enters the bed of the river opposite Indian Creek, where it is wide enough to allow the formation of the tow-path in its bed, the canal being contained between this embankment and the steep mountain-slope that descends to the water's edge. At this place the canal should be again fed from the river by constructing a dam just below the mouth of Indian Creek, which is a stream of considerable size. The canal-line terminates by entering the Youghiogheny at the mouth of Dunbar Creek, immediately after passing under the Fayette County Branch Railroad.

The occupancy of the river-bank below Dunbar Creek by the Southwest Pennsylvania Railroad, whose embankment-slope reaches into the river, would require the canal to be laid in the river if it were continued to Connellsville. The termination at the mouth of Dunbar Creek was chosen on account of the expectation that navigation up to Connellsville would be secured by locks and dams in the Youghiogheny itself, and that the upper pool of this slackwater would at least extend to the end of the canal-line. Since the completion of the survey of the river to West Newton, and after studying it in company with yourself during your tour of inspection about the 1st of September, I am now decidedly of the opinion that the canal should be extended to West Newton, for the following reasons:

If the river were locked and dammed from Connellsville to West Newton, merely as an extension of the canal, with locks of the same size, it would not be much more advantageous for commerce than an independent canal between the same points.

A large surface would be exposed to evaporation, and there would be an increased loss of water from this cause.

Tow-paths would have to be constructed along the whole length of the slackwater.

The interruptions, caused by floods, would be considerable on the slackwater, while the canal would be perfectly free from annoyance from this cause.

The expense of building locks and dams in the bed of the river would probably be at least equal to the cost of the canal, and from the necessities of the case these constructions would be much more exposed to injury, and more difficult to prevent from leaking.

The control of the limited water-supply would be much more effectual on the canal than on the river, and less would probably be needed to keep up navigation.

If the locks in the river below Connellsville were to be made large enough for steamboats there would be a necessity for an increased supply of water, and there seems good reason to fear that such increase could not be obtained during dry summers without constructing large and costly reservoirs.

For these and other reasons I think that the canal-line should be extended to West Newton.

Returning now to the summit of the mountains and following the line of survey eastward, the canal is laid along the side-hill slopes of the Will's Creek Valley, and inclined planes have been freely used, the steepness of the descent making the use of locks of ordinary lifts impracticable except in special localities.

The summit-level extends to a point 1.35 miles east of the eastern portal of the tunnel, and terminates at a plane of 64 feet in height; the level commencing at the foot of this plane is 0.87 miles in length, and ends at a plane 60 feet high; the third level is 1.59 miles long, and the plane at its eastern end is 100 feet in height; the fourth level is 0.86 miles long, terminating at a plane of 35 feet in height; the fifth level is 1.57 miles long, and the plane at its eastern end is 120 feet high; the sixth level is one-quarter of a mile long, and the plane that follows it is 20 feet high. This plane descends into the bed of Will's Creek, to avoid a very bad location on a steep, rocky hillside, where the canal, if built, would have been restricted to 45 feet of width. By the arrangement adopted, the full width of canal is secured, and a pool, or basin-reservoir, is formed at Southampton, 2,000 feet long, 100 feet wide, and more than 7 feet in depth. The pool is formed by a dam 18 feet high and 150 feet long, which turns all the water of Will's Creek into the canal at a distance of 6¾ miles from the eastern end of the summit-level. The seventh level is 2.04 miles long, and ends at a plane 107 feet high. As this level leads out from the pool at Southampton, a guard-lock will be needed for use when a flood on the stream raises the pool above the ordinary level. Savage Run is crossed by this level on an aqueduct of 53 feet span. Incline No. 7 also descends to the bed of the creek, where a pool is formed by a dam at the crest of the falls of Will's Creek; from this pool the canal-line passes through a tunnel 400 feet long, and at once crosses Will's Creek at an elevation of 38 feet above the bed of the stream, by an aqueduct of two spans of 50 feet each; on leaving this it strikes the natural surface, on which it continues for a distance of 1,000 feet, and then recrosses Will's Creek at an elevation of 49 feet above the stream by an aqueduct of two arches, each of 50 feet span. This level is three-quarters of a mile long, and has one dam, one tunnel, and two aqueducts; it is terminated by a plane (No. 8) of 72 feet in height, which takes the canal down to the bed of the stream. The stream is followed for a distance of 400 feet, and the line then cuts through a sharp point, the length of cutting being 200 feet, and its extreme depth 75 feet.

Immediately after leaving the cut, Will's Creek is crossed, at an elevation of 20 feet above the bed of the stream, with three spans of 40 feet each. The line then strikes a terrace, where the cutting on the center line is 3 feet, for a distance of 1,000 feet, when it again crosses Will's Creek at an elevation of 35 feet, with three spans of 50 feet each. From this place this level holds its way along the steep slope of the mountain on the south side of the stream for a distance of 2.03 miles, ending at plane No. 9, which has a height of 115 feet. The tenth level is 0.43 of a mile in length, and ends with a plane of 71 feet height. The next level is 0.58 of a mile in length, and terminates at a plane of 119 feet height, which descends to the bed of Will's Creek, at 13.94 miles from the eastern end of the summit-level. The line was brought down to the creek because it was found to be very difficult to get around the point of the mountain at this place, as the change in direction was 120°, and a nearly perpendicular face of rock had to be passed at an elevation of 115 feet above the valley. Further examinations may result in getting a favorable passage around this point by a tunnel. A new channel is to be made for the creek to the left of its present bed, and a storage-reservoir is located here, feeding directly into the canal.

After passing the point just mentioned, which is opposite the mouth of Gooseberry Creek, by two locks of 8 feet lift, and two levels, each 1,200 feet long, the valley of

Will's Creek ceases to be a narrow ravine, widening out into beautiful meadows, and there are no obstacles of more than ordinary difficulty until we approach the Narrows near Cumberland. A level two-thirds of a mile long, and a plane 40 feet high; another level of about the same length, and a plane 60 feet high; and a third level of 1⅛ miles, with a plane 70 feet high, brings the line to a point six-tenths of a mile south of Bridgeport. Thence we have a level 1.44 miles long, and a plane 55 feet high, followed by a level 1.48 miles long, with a plane 46 feet high, bringing the line to within 1 mile of Cook's Mills Station, on the Pittsburgh and Connellsville Railroad. From this point to Cumberland, a distance of 10.4 miles, there is but one plane, as the canal lies in a wide, open valley, and the descent can be satisfactorily made by locks.

In this distance of 10¼ miles, the fall of the creek is 169½ feet, and this fall will necessitate twenty-one locks, each of 8 feet lift. It is not considered advisable to make the lifts greater than this, as the larger portion of the water-supply between the summit and Cumberland must be drawn from the summit-level. Five of the twenty-one locks must be placed in the Narrows within a distance of 2 miles, as the fall of the stream is greater here than above. In the Narrows the locks are with but one exception at equal intervals, of nearly 2,300 feet, which is not at all a bad condition.

The canal is necessarily taken under the Pittsburgh and Connellsville Railroad, where it crosses Will's Creek, near Cook's Mills Station, and its bottom is placed at a depth of 18 feet below the bridge-chords. Again, 2.6 miles farther on it is necessary to take it under the Cumberland and Bedford Railroad, near Ellerslie Station, at the same depth as at the first-named crossing. At the first place there is ample room under the present bridge for the canal by taking it under the westernmost of the four 100-foot spans, but at the crossing of the Bedford Railroad a new span will be necessitated so as to make room for the canal on the west side of the creek. From this point on, the canal-line lies between the railroad and the bed of Will's Creek, until it reaches the gorge at the mouth of Braddock's Run at the north end of the Narrows.

At four places below Bridgeport the canal is laid in the bed of the stream, and provision is made for a new channel for the creek to the left, the excavated material being taken to form the tow-path embankment, which is also the guard-bank against floods. Wherever the creek-channel is occupied, a natural hill or bank forms the berm-side of the canal, while but a low height of tow-path bank is required to form the canal, the natural surface on which the tow-path is to be placed being generally from 6 to 8 feet above the bed of the creek. By providing in such cases new channels for the creek to the left of the present channels, we are enabled to keep the creek to the left of the canal-line to within a mile of the Narrows, where the canal crosses the creek for the last time by an aqueduct 170 feet long. In a sort distance farther the canal must be taken under the Pittsburgh and Connellsville Railroad embankment and down to the bed of the creek by means of a plane, after which it passes under the Eckhart Branch Railroad, for which an additional arch or a truss bridge must be provided. From this place to Cumberland, the canal and the creek will occupy the Narrows between the railroad on the left and the National Road on the right, and will be separated by a masonry division and guard-wall from 18 to 25 feet high, the canal being on the left next to the railroad. There is room all the way through the Narrows for a canal 70 feet wide* and for a water-way 100 feet wide for the creek, and this is its present average width. The width necessary for canal and creek is obtained by removing the side slopes of the railroad and of the National Road, and supporting these roads by retaining-walls. By these means, though very expensive, there is no difficulty in passing the Narrows with quite favorable conditions of stability for the works of the canal. The canal passes under the National Road where the latter bridges the creek, and this will, therefore, necessitate an additional arch or trussed span, or, preferably, the road-bridge might be destroyed and the National Road carried over the creek and canal by an iron truss-bridge leading to the junction of Center and Mechanic streets, near the northern suburbs of the town. The proposed new bridge would have the advantage of keeping the National Road away from the railroad, and thus making it safer for travel. The canal joins the reservoir-pool of the Potomac River well down in the town, passing under the Baltimore and Ohio Railroad viaduct.

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*The width of the canal at and through the Narrows has been determined by the consideration that, should the canal be extended by this route, the shipment of coal from the George's Creek mines would most probably be made at the mouth of Jennings's Run, 4⅝ miles from Cumberland, and 1⅞ miles north of the Narrows; therefore the section of the canal in the Narrows should be of the full standard width, in order to accommodate the great coal business that already requires, at Cumberland, the passage over the terminal level of from 80 to 100 boats per day.

If the canal were lessened in width, the boats would have trouble in passing each other; and should several ascending boats crowd into the same level, it would be seriously depleted of water, and the passage of the boats would thereby be retarded. This retardation would occur when there was the greatest press of business, and therefore at the very time when it would be most injurious.

That portion of the canal between the mouth of Jennings's Run and the head of the Narrows may be improved in location by crossing the creek just below the gorge at the mouth of Jennings's Run, and supporting a level on the hill-slopes on the left side of the creek, and using a plane of 65 feet height at the same location as that indicated for the plane 32 feet high. The difference in the cost of the earth-works would not be very great, the aqueducts would balance each other, and eight locks would be avoided. The line would be somewhat lengthened by the improved location, but boats could pass over the inclined plane and the longer level in less time then they could over the located line, with seven levels and eight locks. The saving in time would be about 45 minutes.

The eastern slope of the canal, from the summit-tunnel to Cumberland, must mainly depend for its water-supply upon the summit-feeder, but arrangements have been made to turn the available flow of Will's Creek into the canal by means of dams and short feeders and by occasionally bringing the canal into the bed of the stream, as at Southampton and at the falls of Will's Creek. Feed-water is also taken four times between Bridgeport and Cumberland, at each of those places where the bed of the creek is to be occupied by the canal and a new channel made for the creek. There are several small streams emptying into Will's Creek upon which reservoirs could be made, the largest ones being Little Will's Creek, Jennings's Run, and Braddock's Run, each of which would yield water enough to replenish the ordinary losses on 5 or 6 miles of the canal.

There was neither time nor a sufficiency of funds to make the necessary examinations in regard to the supply of feed-water for the summit-level of the canal. As outlined in my report of explorations made in 1873, the supply must be stored in large reservoirs, to be located in the valley of Castleman River above Meyersdale, and should be sufficient to supply the eastern slope of the canal as far as Cumberland, in order to guard against a failure in the additional supplies arranged for along this slope; and also to supply the western slope as far as the first feeder below Meyersdale.

WATER-SUPPLY.

In determining the amount of water needed for the use of the canal, I have been guided by the table of consumption of water deduced from the latest French practice, as stated by Graeff, which you sent me for use. This table shows that the maximum losses, by evaporation, absorption, filtration, leakage, false maneuvers, and other incidental causes on a canal built in the ordinary manner, of 48½ feet width at water-line, 33 feet width at the bottom, and 5½ feet depth of water, may be put, after the canal has been in use for a few months, at from 4 to 6 cubic feet per running foot in twenty-four hours. To be safe in our estimates, we will take the larger amount given in the table, and put these losses at 6 cubic feet per running foot in twenty-four hours. To apply this experience to the canal under consideration, which is considerably wider and deeper than that given in the table, we will first endeavor to separate the losses by evaporation from the other losses enumerated above, and, after estimating what would be the increase due to the evaporation on our wider canal, then determine what would be the losses due to the other causes by reason of the increased cross-section. Graeff does not give an estimate of the loss chargeable directly to evaporation, but from his remarks he apparently considers it about one-quarter of an inch in depth in twenty-four hours. He does, however, state that the losses due to all the above-mentioned causes on concreted sections of canal vary from 0.24 to 0.38 of an inch in twenty-four hours, and presumes that this loss is mainly due to evaporation. Now, evaporation is very uniform in its action in an open and cultivated country, but the other causes of loss vary with the construction of the canal and the nature of the soil through which it passes. It is evident that a canal which is mostly in embankment will lose more than one which is mostly in excavation. We therefore feel warranted in assuming the smaller estimate, 0.24 of an inch, as the measure of loss due to evaporation.

As this figure agrees very well with estimates derived from other sources, it has been adopted, and, for convenience in computation, has been taken at 0.25 or one-fourth of an inch.

This makes the evaporation on the Marne-Rhine Canal, which is the one described by Graeff, 1 cubic foot per running foot in twenty-four hours, leaving 5 cubic feet per running foot in twenty-four hours chargeable to the other losses, which losses may be considered as mainly dependent on the wetted perimeter.

The water-width of our canal is 1.44 times that of the Marne-Rhine Canal, and therefore the evaporation will be 1.44 cubic feet per running foot in twenty-four hours. The same proportion holds between the wetted perimeters of the two canals; and, neglecting the difference in depth, the losses due to other causes should therefore be put at 7.20 cubic feet per running foot in the same time. But as the pressures on a square foot of bottom in two canals of different depths vary as those depths, and as the same law holds on the side slopes, it seems proper to estimate that an increase in pressure will cause an increase in losses by filtration and leakage at mechanical structures. The depths of the two canals are 5½ and 7 feet, and, the latter being 27 per cent. the greater, we should add 27 per cent. to the figures just obtained. This will give us 9.14 cubic feet per running foot in twenty-four hours for all losses except those due to evaporation, and adding the latter we will have 10.58 cubic feet for losses of all kinds.

Graeff gives many other sources of loss which must be considered as affecting the longitudinal slopes of a canal, such as difference in size of locks, crowding of boats into short levels, and incidental losses due to general navigation. These last losses may arise from the surfaces being disturbed so as to cause water to escape over the waste-wiers and other low places on the banks when unusually large waves are made by passing boats, or they may be due to an excess of water poured into a level from the one above when the latter is emptied for repairs. This excess would escape over the waste-wiers and lock-gates.

A partial remedy for these losses would be provided by placing the tops of the waste-wiers and the top of the lock-gates about six inches higher than the normal surface of the water in the canal, for the purpose of retaining a portion of the surplus water that must occasionally be thrown into a level. The quantity that could be saved in our canal in this way would amount to 184,800 cubic feet on a level one mile long. Considerable losses from oscillations of the water-surface, due to other causes, would be materially lessened by this plan of construction. To cover these losses, which do not admit of accurate determination, we will add ten per cent. to the figures previously found, and we thus obtain for losses of all kinds on the longitudinal slopes (except those due to movements of boats that do not pass the summit-level) 11.64 cubic feet per running foot in twenty-four hours. This is equivalent to 40.68 cubic feet per mile per minute, and, neglecting fractions, we will finally assume for the losses mentioned above 42 cubic feet per mile per minute. These figures represent the rate of loss on any longitudinal slope of canal, without regard to the number of boats that may pass over it, provided they all enter or traverse the summit-level, and this loss must be replenished by water drawn from the summit-level and from the auxiliary feeders. The section from the summit to the first feeder is of course entirely dependent on the summit-level for its supply.

We will consider the summit-level of our canal to be 6 miles long, which is very little in excess of the true length. Graeff's formula for the consumption of water on the summit-levels of canals built in the usual way is, $\frac{2\,e\,n}{L}+$ (from 5 to 11,) and for concreted summit-levels $\frac{2\,e\,n}{L}+2$. Both of these formulas give the consumption per running foot in twenty-four hours. L represents the length of the level in feet, e the prism of lift in cubic feet, and n the maximum number of boats passing in one day. It will readily be seen that these formulas are based on the expenditure of two lockfuls of water to each passing boat; a larger consumption than is estimated in American practice. So large a consumption of water for lockage could only take place on the hypothesis that all the boats entering the summit-level are going in the same direction, which, to say the least, is highly improbable. If they should alternate regularly at the locks, but one lockful of water would be expended by each boat. The practice in the United States is to allow one and a half lockfuls of water for each boat that passes the summit level, and experience seems to show that this allowance is ample. This amount was also the basis of the original estimate, made for the same summit-level that we are now discussing, by the Board of Internal Improvements in 1826. We will, therefore, accept it as the basis of our calculations, and assume one hundred as the maximum number of boats that will pass the summit-level in one day. At the eastern end of the summit-level is an inclined plane 64 feet high. For reasons given in full on pages 5 and 9 of my report on "inclined planes," (printed as Ex. Doc. No. 275, H. of R., 43d Congress, 1st session,) the expenditure of water at this plane will about equal that at an 8-foot lock. At the western end of the summit-level is a 6-foot lock. The latter will, therefore, require less water than the plane at the eastern end, but, for convenience in calculation, we will assume an average lock of 7 feet lift at each end of the summit-level; we will also change the $2\,n$ of Graeff's formula to $1\frac{1}{2}\,n$.

A 7-foot lock consumes 16,800 cubic feet at a lockage. One hundred and fifty lockages during twenty-four hours will consume 2,520,000 cubic feet, which, for a level 6 miles long, is at the rate of 79.5 cubic feet per running foot in twenty-four hours. If to this we add 8 cubic feet as the average of the losses by evaporation, leakage, filtration, &c., (expressed in the formula as "from 5 to 11," we have for the total loss on the summit-level 87.5 cubic feet per running foot in twenty-four hours, which is 2,773,440 cubic feet for the entire summit-level.

We will now determine the additional quantity of water which must be furnished by the summit-level in order to make good the losses on those portions of the adjacent slopes which depend on it for their supply. Owing to the small quantity of water that can be gathered on the eastern slope, the whole of this slope as far as Cumberland will be considered as dependent on the summit-level. Of the western slope a distance of 4,800 feet is similarly situated.

The eastern slope is 28.84 miles in length, from which we will deduct 2 miles for the aggregate length of the planes, leaving 26.84 miles on which to calculate losses. Using the loss per mile per minute previously determined for slopes, (42 cubic feet,) we obtain for the daily loss per mile 60,480 cubic feet, and for the daily loss on the eastern slope 1,623,280 cubic feet. A similar calculation shows that the daily loss on that portion of the western slope which is dependent on the summit-level, and which we will call in round numbers one mile, is 60,480 cubic feet. Summing up the losses thus obtained for the summit-level and its dependent slopes, we obtain as the grand total to be supplied in one day from the summit-reservoirs 4,457,200 cubic feet, equal to 51.6 cubic feet per second.

The season just passed was not favorable for determining the minimum flow of the Castleman River at the place where the feeding-reservoir, heretofore mentioned, would be constructed, and reference must be made to the gaugings of that stream made in 1825. (See Annual Report of the Chief of Engineers for 1874, Part I, page 537.) These gaugings show that the flow of Castleman was greater than the quantity found to be required, except in the month of July; we will, therefore, take the gauging of July 12, to represent the minimum duily flow for a term of one hundred days, covering July, August, and September, these months being considered the dryest of the year.

The summit-reservoir will be one-half mile above the mouth of the Flaugherty Creek; and as the full flow of Flaugherty Creek can be turned directly into the summit-level of the canal in the manner that will be described under the head of "estimates," we can assume that the supply at the mouth of Flaugherty will be 46 cubic feet per second. This will leave a deficiency of 5.6 cubic feet per second to be provided by means of reservoirs.

The loss by evaporation on the reservoir becomes now of very considerable importance, as this loss must also be provided for in estimating the contents of the reservoir. We have previously determined the loss from evaporation to be equal to one-fourth of an inch of the depth of the surface in twenty-four hours. We may presume that losses from other causes will be small, but, to provide for them, we will add one-eighth of an inch, or half that found for evaporation. The Pleucher reservoir surveyed for the canal project of 1825, (Report of Chief of Engineers, 1874, Part I, page 530,) was estimated to have a capacity of 4,679,029 cubic yards, and its surface area was 1,040,600 square yards.

We will assume that the reservoir proposed near the western end of the summit-level will be equal in capacity to the Pleucher reservoir and have an equal surface, and that both reservoirs are built. The loss by evaporation on these two reservoirs would be 585,337 cubic feet per day, or 58,533,700 cubic feet in one hundred days. The quantity to be stored to supply the deficiency as found above (5.6 cubic feet per second) is 48,384,000 cubic feet, and the sum of these two quantities is 106,917,700 cubic feet. The two reservoirs would have a capacity of 252,667,000 cubic feet, which is more than double the amount that would be required.

The local necessities of the coal-trade for the George's Creek coal-basin indicate that in all probability the extension of the Chesapeake and Ohio Canal would give rise to a very considerable traffic between Cumberland and the mouth of Jennings's Run, which would be the point on the canal nearest to the coal-mines. The distance by canal from Cumberland is about 4 miles; the ordinary losses on this section of the canal are included in the previous estimates, but such a local navigation as that suggested would add largely to the consumption of water for lockage. The present amount of the coal-trade at Cumberland suffices to send out an average of from forty to fifty loaded boats per day, and receives about the same number of empty ones, thus requiring from eighty to one hundred lockages in twenty-four hours. Assuming that one-half of this business would be transferred up to Jennings's Run, such a change would increase the daily consumption of water on this section by about fifty lockages, and this would have to be made good from the summit-level or from intermediate feeders. It amounts to 960,000 cubic feet per day, and is an averge of 11.11 cubic feet per second. This additional consumption could be provided for by a reservoir on Jennings's Run.

The measure of loss found for the usual causes, which was determined to be 42 cubic feet per mile per minute, gives 60,480 cubic feet per mile in twenty-four hours, and if efficient feeding-supplies were provided at intervals of ten miles, a constant flow of 7 cubic feet per second would supply the loss—and for shorter distances in proportion.

The interval between the first and second places of receiving feed-water on the western slope is 4.4 miles, and 11 feet is the greatest lift of lock on this section. Assuming that one hundred boats would pass this lock in one day, the excess of consumption of water in lockage over that of the 6-foot lift-lock at the west end of the summit-level is 1,200,000 cubic feet per day, and the ordinary losses would be for 4.4 miles, 266,112 cubic feet, their sum being 1,466,112 cubic feet, which is equivalent to a loss of 17 cubic feet per second. The second interval is 7.4 miles, and the greatest lift of lock thereon is 12 feet, requiring, on the same reasoning as before, 8 cubic feet per second to supply its losses. The next interval extends a distance of 10.8 miles to Shoo-

Fly Tunnel, (Pittsburgh and Connellsville Railroad.) The greatest lift of lock on this section is 16 feet, and this will necessitate a supply of 19 cubic feet per second in order to provide for losses and for the difference in lift of lock over the lift used on the preceding section. Beyond this point there are no locks of greater lift than 16 feet, and consequently there will be no greater demand for water than on the section last named. Below Shoo-Fly Tunnel the canal is fed at the following places: 12 miles below the tunnel and nearly 3 miles below Confluence, 8 miles farther on at Ohio Pyle Falls, and 9½ miles farther on at Indian Creek. The length of canal supplied by the last-named feeder is six miles, being the distance between Indian Creek and Connellsville, where the canal survey ended. If a considerable local navigation should spring up at Confluence, or at any other point on the western slope, it would have to be accommodated in the same way as the local navigation at Jennings's Run.

From the statement above given there seems no reason to anticipate that reservoirs will have to be built anywhere on the western slope below Meyersdale. For further information on the water-supply of this slope, reference is made to Report of Chief of Engineers for 1874, Part I, page 541. On the eastern slope a reservoir will probably be needed at Jennings's Run, in order to supply the anticipated local navigation at that place. Should there be any fear that the canal supply will not hold out, reservoirs may subsequently be built on Will's Creek, near its head, on Little Will's Creek, and at various points mentioned in the report of the Board of Internal Improvements. There seems, therefore, to be no reason to dread an insufficiency of water for the extension of the Chesapeake and Ohio Canal, provided the streams continue to yield the same amount of water as in 1825. The time and funds thus far appropriated were all expended on the survey proper, and the question of water-supply has of necessity been discussed from the old data. Whether the change in the face of the country since 1825 has decreased the amount of water in the streams can only be ascertained by a careful series of observations made during a dry season.

It should be borne in mind that there will, in all probability, be no scarcity of water except in mid-summer and the early part of autumn, and that these provisions and computations only apply to that portion of the year.

For a discussion of the amount of water that can probably be stored from the rain-fall on the headwaters of the Castleman, I would respectfully refer to the following extract from my report of January 30, 1874. (Report of Chief of Engineers, 1874, Part I, page 507.)

"If we consider the summit-supply as dependent on the average rain-fall and the catchment-basins, we find that the catchment-basin of the Pleucher reservoir is very nearly 12 miles long and 5 miles wide, and has an area of 60 square miles. The average annual rain-fall at Pittsburgh, Pa., was 34.96 inches, for eighteen years; at Marietta, Ohio, 41.58 inches, for twenty-eight years; at Portsmouth, Ohio, 38.20 inches, for fifteen years; at Carlisle, Pa., 34 inches, for six years; and at Gettysburgh, Pa., 38.80 inches, for seven years. If we take an average of these as representing the annual rain-fall for the region under consideration, we get 38 inches per annum. Applying this to the catchment-area given, and assuming that but one-third of the quantity is caught by the reservoir, we have an annual quantity of 1,698,965,300 cubic feet—enough to fill the reservoir thirteen times; and the Piney Run Reservoir with a catchment-area of 12 square miles would also be filled thirteen times; the total annual supply by rain-fall being 2,038,758,360 cubic feet, which gives an adequate supply for the use of the canal during a period of twenty-five months, with allowances for evaporation of reservoirs and loss in feeding.

"Again, if we take an average of the gaugings in March and June as representing the available rain-fall that will be caught by the Pleucher reservoir, we get 1,829,088,000 cubic feet as the annual supply, whereas the consumption for the use of the canal would be for ten months, 780,000,000 cubic feet, or only about 43 per cent. of the estimated supply. This estimate of consumption is twice as great as that assumed by the Board of Internal Improvements."

In relation to the system of inclined planes to be used on the eastern slope, the intention was to use double-track planes, and to carry the boats in caissons filled with water on carriages so made as to keep the caissons in a horizontal position. The boat would be taken into and discharged from the caisson at the lower end of the plane, in the same general manner as from the boat-carriages, as described in my former report on inclined planes; but at the upper end of the plane the canal-level would be terminated by a masonry chamber with one pair of gates, and the upper end of the caisson would likewise be provided with a gate or door. The caisson with the boat would be drawn up into the masonry chamber, and a connection as nearly water-tight as practicable would be made between them; the caisson-gate and the lock-gate would then be opened, and the caisson would then become, to all intents and purposes, a continuation of the upper level of the canal, and the boat would at once pass into the canal proper; boats would be taken into the caisson and down the plane by the reverse operation. If these caissons are kept filled with water, they will always balance each other, and only a small force will be required to start them and keep them in motion. If the ascending boat should happen to be empty, no more water need be carried up than would be required to float it, and a preponderance would thus be given to the descending caisson, which would suffice to operate the plane without the use of the hoisting-machinery. If water-tight boxes be attached to the caissons, and the one on the descending caisson be filled with water, while that on the ascending one is left empty, a similar preponderance would be established, and the descending caisson would draw up the ascending one.

There seems to be no doubt that a canal operated entirely by double-track inclined planes, on which the boats are water-borne, could be worked with a much less supply of water than an equivalent length of canal with locks.

Owing to ill-health, pressing duties in attending to the field-surveys, and the desire to complete this report at an early date, so that it might be presented at the beginning of this session of Congress, I have not been able to work out, to a satisfactory result, the detailed construction of the caisson plan for planes.

The masonry chambers at the upper ends of the plane have been sketched on the profiles of the planes, which are shown without distortion on the profile sheets, but their costs have not been estimated for. On the contrary, double-track planes, with the ordinary open carriage, have been estimated for, as stated under the head of "estimates."

I purpose working up the caisson plan, to determine how far it may be practicable, and its value as a substitute for locks. I will be pleased to transmit at some future time my conclusions, as a part of the record of the survey and of the study for this trans-Allegheny water-line.

WILL'S CREEK ROUTE—ESTIMATE OF COST.

In estimating the quantities and cost of the work, care has been taken to make them in excess rather than to study the making of minimum quantities, and in all cases a first-class character of work and construction has been considered.

So great a proportion of the line surveyed being on the slopes of the hills coming down to the river, there is always an excess of excavation over the embankment at any particular locality, or such excess can be provided by a slight change of the center line, by laying it higher on the side-hill slopes, so that the embankment that may be required at any special place is to be made from the excavation at or very near the same place, and the cost of such sections is estimated in excavation only; and the excavation being so generally in rock, as before remarked, there is always an abundance of this material at hand for laying slope-walls, and for protection on embankment-slopes, where liable to be washed by the river-floods; and to such an extent do these conditions obtain, that thoroughly built masonry retaining-walls may not often be required.

There will be considerable difficulty in procuring enough clay or shale or slate soils, or earth, to render the embankments water-tight, especially at those places where the rock-excavation is in excess. At a great many places, however, there can be an abundance of clayey earth procured from the flat bottom-land on the opposite side of the river or creek, which can be readily carted across at almost any time, as a reasonably low stage of water generally obtains except during floods.

The division embracing the eastern slope from Meyersdale to Cumberland does not come under the general character just described, as on nearly the entire length of the division a sufficient quantity of earth is to be had for making water-tight embankments.

The grading for the inclined planes is estimated for a width of 50 feet, making provision for a double track either for the carriages described in my report on planes, or for the caissons alluded to in this report.

The aqueducts, of which there are seven on the eastern slope, vary in length from 50 to 100 feet. There are six on the western slope varying in length from 100 feet to 430 feet, these lengths being estimated between the faces of the abutments. The aqueducts are designed with segmental circular arches, of spans of 50, 60, and 70 feet, and versed sines varying from one-sixth to one-fourth the span, with piers of 6 and 8 feet thickness and of 12 to 14 feet height. Plans and drawings of some of these structures are transmitted herewith as types.

The profile-sheets show cross-sections of the line of the canal at frequent intervals, illustrating the general character of the excavation and embankment for forming the water-prism.

The most important feature of the route is the summit-tunnel which is located near Meyersdale, Pa., on the same line and between the same points recommended by the Board of Internal Improvements fifty years ago. The more careful surveys of the past year show it to be three and three-quarters miles in length, with an eastern approach cut 2,300 feet long, and a western one 7,100 feet (one and one-third miles) in length. The greatest height of the summit above the grade-line of the tunnel is 924 feet.

The section of the tunnel when completed will be 46 feet in width, with sides nearly vertical to a height of 10 feet, covered with an elliptical arch of 46 feet span and 18 feet rise. (See section on profile-sheet No. 1.) The arch-lining is to be of brick, 22 inches thick, and the side walls of stone or brick, as may be found most convenient and economical. This tunnel being in the lower coal-measures, which are not horizontal, will pierce the various strata of sandstone, shale, slate, coal, and limestone, and the probability is that it will have to be lined throughout to render it water-tight; for this reason, a bottom lining of concrete is estimated for. The vertical sides and elliptic form of the arch will allow passing boats the greatest room and close approach to the sides of the tunnel, while the clear headway of 21 feet above the water-surface is as little as can well be allowed for ventilation, and to get a strength of arch overhead, the radius of the crown being quite nearly 28 feet. (See profile-sheet No. 1.)

The surface-profile of the tunnel-line shows two depressions suitable for working shafts for excavating the tunnel, and these will divide the tunnel into three sections, the western section being 8,308 feet long, and the middle one 6,000 feet long, and the eastern one 5,492 feet long. The western shaft will be 700 feet deep, and the eastern one 576 feet deep. The tunnel can be completed in six and one-half years from these two shafts; that is to say, two years will be occupied in taking out the approaches and sinking the shafts, and four and one-half years in excavating and lining the tunnel, dependent on the greater length of the western section of the tunnel. This allowance of time is based on an estimated progress of 3 feet per day at each working-face. I have no doubt that a daily progress of 4 feet is quite possible, but the loose character of the material and the necessity for shoring the roof and sides may make it less. The Nesquehoning tunnel in Pennsylvania, in the same general character of rock, progressed in heading 100 feet per month in conglomerate rock, and 160 feet per month in red shales, while the widening averaged a daily progress of 160 feet; or more than 5 feet per day of general average.

I have analyzed the prices and cost of the tunnel-work in detail in regard to excavation or mining the rock, drawing it to the shaft, raising it, drawing it to deposit in banks, pumping of water with a 60 horse-power engine worked to its full capacity, and blowing of air to the working-faces in the tunnel. The prices given cover all these considerations, with an addition of 10 per cent. profit to the contractor. Owing to the great width of the tunnel and its consequent cost per linear foot, the open approach cut can be continued until it reaches a depth of about 78 feet before equaling the tunnel in cost per linear foot; and this may account for the lesser length of tunnel as compared with the length of tunnel recommended in 1828 by the Board of Internal Improvement, notwithstanding the fact that the present tunnel has been put 28 feet lower than the former. It is assumed that the tunnel will be operated by steam-tugs, or by endless chains or ropes, kept in motion by fixed machinery; either of these methods will obviate the necessity of providing towing-paths in the tunnel, which would be expensive structures in themselves, and in addition would increase the width of the tunnel, and consequently the span of the covering arch. This would materially weaken the arch, unless accompanied by a corresponding increase in height, and an increase in height would add greatly to the amount of excavation to be made, besides necessitating an increase in the thickness of the lining-arch.

If a considerable expense were incurred in the construction of one or two towing-paths in the tunnel, and soon after steam navigation should be established on the canal, then the cost of having provided the towing-path would be a heavy and unnecessary item of capital to carry in yearly interest. In my report of 1874, I estimated the increased cost of tunnel for one towing-path at $500,000, the interest on which, at 6 per cent., would be a sum more than sufficient to operate an efficient number of tugs (say six) to operate the tunnel to its full capacity.

The approach cuts are designed to have a tow-path of 8 feet width on each side, up to the portal of the tunnel, as a matter of utility, and to enable boats to be delivered and taken at the portals of the tunnel, if it should be operated by an endless chain or wire rope, or in some other similar manner. These towing-paths would also act as berms to catch any *debris* that might be dislodged from the slopes of the cut, for which purpose they may be considered indispensable.

That portion of the approaches to the tunnel in which the canal-prism is in earth-excavation, is designed to have vertical side-walls of stone in order to maintain the width of 45 feet provided in rock-cuts and to support the towing-paths.

THE SUMMIT-LEVEL, SIX MILES LONG.

West approach.

12,100 cubic yards earth-excavation, at 20 cents	$2,420 00
5,000 cubic yards rock-excavation, at $1	5,000 00
454,890 cubic yards earth-excavation, at 30 cents	135,467 00
279,900 cubic yards rock-excavation, at $1.25	349,875 00
25,000 cubic yards earth-excavation, (new channel for Flaugherty Creek,) at 20 cents	5,000 00

350 cubic yards slope-wall in west basin, at $1.50	$525	00
150 cubic yards culvert-masonry, at $8	1,200	00
4,760 cubic yards side-wall, at $1.50	7,140	00
1 lock of six feet lift on rock foundation	17,600	00
Drainage-sluice and waste-weir	2,800	00
2 street-bridges in Meyersdale	4,500	00
Damage to Meyer's mill-race	250	00
23 acres land-damages, at $100	2,300	00
Sum of items of cost, west approach	535,077	00

TUNNEL PROPER, 19,800 FEET—THREE AND THREE-FOURTHS MILES LONG.

1,066,270 cubic yards excavation, at $4	$4,265,080	00
41,250 cubic yards concrete bottom, at $6	247,500	00
39,600 cubic yards side-wall masonry, at $15	594,000	00
90,810 cubic yards brick-arch masonry, at $12.50	1,135,125	00
49,860 cubic yards packing back of arch, at $3	149,580	00
9,440 cubic yards shaft-excavation, at $13.25	125,080	00
3,810 cubic yards brick lining of shafts, at $12.50	47,625	00
2,400 cubic yards portal-masonry, at $12.50	30,000	00
Sum of items	6,593,990	00

If the cost of excavating and lining the shafts be taken from this sum, the cost of the tunnel is almost exactly $6.02 per cubic yard; and the cost of the shafts is very nearly $18.30 per cubic yard. The lining of the tunnel costs $2 per cubic yard.

EAST APPROACH.

115,190 cubic yards earth-excavation, at 30 cents	$34,557	00
32,480 cubic yards rock-excavation, at $1	32,480	00
Farm-bridge	1,500	00
Changing county road at portal of tunnel	150	00
Drainage-sluice and waste-weir	2,800	00
Plane, 64 feet high, east end summit-level	51,530	00
Five-sixths of a mile grubbing and clearing, at $400	333	50
20 acres land-damage, east end level, at $30	600	00
30 acres land-damage for deposit of spoil-banks, at $100	3,000	00
Sum of items	126,950	50

Summary of estimates for summit-level.

West approach	$535,077	00
Tunnel proper, with 10 per cent. contingencies	7,253,389	00
East approach	126,950	50
Seven years' engineering superintendence	42,000	00
	7,957,416	50

The western approach cut crosses the present bed of Flaugherty Creek, and also the mill-race that supplies Meyer's mill. To carry the creek across the cut at this place would require an aqueduct of 100 feet span, at a height of 46 feet above the towing-path surface, and consequently the cheaper plan is to turn the creek across the valley above the portal of the tunnel by a dam and new channel as estimated, and to form the pool of the dam so as to connect with a feeder to the mill-race.

The grade of the canal is low enough to receive the water from the tail-race of Meyer's mill, and thus the mill-race practically feeds the canal from the reservoir formed on Flaugherty Creek.

The planes are estimated for double tracks in conformity with the general plan therefor submitted in my supplemental report on "Inclined Planes," dated March 30, 1874, the quantities of work and material having been carefully determined for each plane. (See Report of Chief of Engineers for 1874, Part I, page 550.)

The quantities of excavation, masonry, and other items of the cost of the construction of the canal have been grouped into characteristic sections.

FROM SUMMIT-LEVEL TO SOUTHAMPTON, EIGHT MILES.

From the plane at the east end of the summit-level to the plane next below Southampton, a distance of eight miles, the line lies along the side-hill slopes on the south side of the valley of Will's Creek, following closely the contour-line corresponding to the grade of the canal, (the excavation about equals the embankment,) descending by planes at proper and convenient places to the bed of the valley. (See profile and map.) It may be described in detail as follows: After leaving incline No. 1, the line crosses the mouth of Laurel Run, and passes along a steep, rocky cliff, about one mile above Glencoe, at an elevation of 40 feet above the grade-line of the railroad. Along this cliff, for a distance of 500 feet, the width of the canal is contracted to 45 feet, and the tow-path embankment is formed on top of a retaining-wall. (See profile sheet No. 2, section at station 563.) The canal descends to the valley by a plane 120 feet high, and in a short distance falls into the bed of the stream by a plane 20 feet high, thence it lies in the bed of the stream for a distance of 2,000 feet in the pool of the dam for supplying water to the saw-mill at Southampton, and then lies along the hill-slopes for a distance of nearly two miles, coming down to the valley by a plane 107 feet high. The canal is brought into the creek at Southampton to avoid a perpendicular rock-cliff on the right-hand side just above the saw-mill, the canal leaving the pool along the mill-race. A new dam is estimated for, which is to be placed about 500 feet below the present dam. The low ground of each bank of the pool is to be excavated so as to make as large a reservoir as possible, the earth to be used in the dam.

The flouring-mill and residence at the upper end of this pool and the saw-mill below would be destroyed. A guard-lock is provided at the exit from this pool, to guard against the effect of floods in the stream. During the ordinary stage of the stream this lock would remain constantly open, and the daily flow of the stream would be led into the canal through the lock; but in time of floods the lock would be closed, and have a lift equal to the height of the flood-surface above the ordinary level of the pool, while the surplus water would flow over the crest of the dam. This would be the first place at which the available flow of Will's Creek would be fed into the canal. The dam would be built on a rock foundation. (See special map of this place, appendix-sheet A.)

Savage Run is crossed by this level by an aqueduct-arch of 53 feet span and 17 feet 8 inches rise. (See special plan, appendix-sheet B, and plans of structures, sheet No. 1.)

ESTIMATE.

447,750 cubic yards earth-excavation, at 20 cents	$89,550	00
155,100 cubic yards rock, (loose,) at 50 cents	77,550	00
155,210 cubic yards rock, (solid,) at $1	155,210	00
143,410 cubic yards embankment, at 30 cents	43,023	00
44,530 cubic yards support-wall, at $6	267,180	00
Savage Run aqueduct on rock foundation:		
506 cubic yards arch-masonry, at $15	7,590	00
1,948 cubic yards pier and side-wall masonry, at $12.50	24,350	00
4,753 cubic yards backing and wing-masonry, at $10	47,530	00
Preparing foundation	350	00
547 cubic yards culvert-arch masonry, at $12.50	6,837	50
822 cubic yards culvert-masonry, at $8	6,576	00
460 cubic yards paving culverts, at $2.50	1,150	00
Plane No. 2, 60 feet height	42,350	00
Plane No. 3, 100 feet height	60,180	00
Plane No. 4, 35 feet height	34,712	00
Plane No. 5, 120 feet height	79,755	00
Plane No. 6, 20 feet height	28,375	00
Plane No. 7, 107 feet height	67,134	00
Guard-lock, 8 feet lift, (on rock)	19,950	00
Towing-path bridge on dam	1,800	00
Six drainage-sluices and waste-weirs	16,800	00
Four county and farm road bridges	5,800	00
Seven miles grubbing and clearing, at $400	2,800	00
Three acres land-damages, at $20	600	00
Special damages at Southampton	20,000	00
Engineering superintendence	8,000	00
	1,115,152	50

FROM SOUTHAMPTON LEVEL TO BRIDGEPORT, 6.45 MILES.

This section includes eight levels, with six planes and two locks. The seventh plane descends into the bed of the creek, just above the falls of Will's Creek, and the canal-line occupies the stream for a distance of 800 feet.

The falls are formed by a well-defined ledge of rock lying squarely across the creek at a very narrow place. (See appendix-sheet C.) It is proposed to build a dam across the creek on the crest of the rock causing the falls, and to excavate the small flat area just above, so as to form a small feeding-reservoir with a guard-lock at the end of the dam, and with a towing-path bridge over the dam. From this pool the canal must pass through a high rock-point by a tunnel of 400 feet length in solid rock, to be of the same dimensions as the summit-tunnel, with the addition of a tow-path 8 feet wide. This tunnel will not require to be lined. The line then crosses the creek by an aqueduct of two spans of 50 feet each and 16 feet 8 inches rise, (see appendix-sheet D,) and in a distance of 1,000 feet again crosses the creek with an aqueduct of two spans of the same dimensions as the last one, and in a distance of 1,500 feet descends by a plane 72 feet high to the bed of the stream. At this place a new channel is proposed on the left in order to pass the creek alongside of the canal. A strong guard-bank is provided for. (See appendix-sheet E, and plans of structures, sheet No. 3.) The line then cuts deep into a sharp point by the side of a deep cut for the Pittsburgh and Connellsville Railroad at a depth of 12 feet below the grade of the railroad. (See profile-sheet No. 4, section at station 793.) Because of the depth of this cut, and of its being in rock, the canal-section is contracted to 45 feet, which contraction continues to the succeeding aqueduct. Will's Creek is here crossed again by an aqueduct of four arches, of 50 feet span and 7 feet rise, at a grade elevation of 18 feet above the creek. (See plans of structures, sheet No. 4.) The line is then supported on a low terrace for a distance of 700 feet, and Will's Creek is again crossed at Fairhope by an aqueduct of three arches of 50 feet span and 16 feet 8 inches rise, at an elevation of 33 feet above the creek.

The mill-race that feeds the Fairhope saw-mill is taken under the wings at the east end of this aqueduct by a 9-foot culvert, (see plans of structures, sheet No. 4,) and it is passed under the embankment in a similar manner before the next aqueduct is reached. (For plans of aqueduct at Fairhope see plans of structures, sheet No. 5, and appendix-sheet H.)

From Fairhope the line is supported on the slope of the mountain, on the west side of the creek, cutting deeply into the point of a rock-bluff just below Fairhope. (See profile-sheet No. 4, section at 834.) It has a plane 115 feet high, one 71 feet high, and one 110 feet high, the latter descending into the bed of the stream at this place in order to avoid a very difficult and steep rocky point alluded to in the general description of this portion of the Will's Creek route. The location from the rock-point bluff, just below Fairhope, to this place is not a favorable one, as the mountain-slope is very steep, has a loose soil, and is covered with loose surface-rock, fallen from some rock-ledges higher up on the mountain.

The canal is passed around Gooseberry Point by two locks, of 8 feet lift each, in the bed of the stream, a new channel for the creek being made on the left. A feed-culvert is provided for the dam that turns the creek into the new channel in order that all the available water of the creek may be fed into the canal at the foot of plane No. 11.

From this point to Bridgeport there are no conditions of unusual character affecting the location; two levels and two planes occur, as shown on profile-sheet No. 5. Some examination was made with a view of substituting four planes, between Fairhope and Gooseberry Point, for planes Nos. 9, 10, and 11, but without a satisfactory result.

An unusually deep tow-path embankment confines the canal-prism against the opposing mountain-slope just after passing Gooseberry Point. (See profile-sheet No. 5, section at 1019.50.)

ESTIMATE.

289,150 cubic yards earth-excavation, at 20 cents	$57,830 00
31,000 cubic yards rock-excavation, (loose,) at 50 cents	15,500 00
299,800 cubic yards rock-excavation, (solid,) at $1	299,800 00
30,000 cubic yards tunnel-approaches, (rock,) at $1	30,000 00
24,000 cubic yards tunnel-excavation, at $2.75	66,000 00
42,570 cubic yards channel excavation, at 20 cents	8,514 00
291,660 cubic yards embankment, (borrowed,) at 30 cents	87,498 00
4,931 cubic yards arch-masonry, at $15, (aqueduct)	73,965 00
8,509 cubic yards of pier and side-wall masonry, at $12.50, (aqueduct)	106,362 50
14,831 cubic yards backing and wing-masonry, at $10, (aqueduct)	148,340 00
Contingencies (small) 3 per cent., (aqueducts)	9,860 00
440 cubic yards culvert-arch masonry, at $12.50	5,500 00
2,462 cubic yards culvert-masonry, at $8	19,696 00
780 cubic yards support-wall, at $6	4,680 00
500 cubic yards slope-wall masonry, at $6	3,000 00
Plane No. 8, of 72 feet height	48,925 00
Plane No. 9, of 115 feet height	84,990 00
Plane No. 10, of 71 feet height	46,305 00
Plane No. 11, of 110 feet height	79,735 00
House for lock-keeper	1,250 00
Two locks, of 8 feet lift each, on rock	44,168 00
Two guard-locks, of 8 feet lift, on rock	44,168 00
Plane No. 12, of 48 feet height	39,587 00
Plane No. 13, of 60 feet height	49,625 00
Four drainage-sluices and waste-weirs	11,200 00

Three dams, two with feed-culverts	$10,000 00
Two tow-path bridges	3,000 00
County-road bridge at Fairhope	2,000 00
Road at Tub Mill Run, (crosses on grade of plane)	25 00
Five miles grubbing and clearing, at $400	2,000 00
Special damages at Fairhope	5,000 00
Forty acres land-damage, at $20	800 00
Engineering superintendence	9,000 00
	1,418,323 50

BRIDGEPORT TO COOK'S MILLS RAILROAD-BRIDGE, 5.44 MILES.

This section presents no great difficulty. Coming from the foot of plane No. 13, the line turns the hill at the west side of the town of Bridgeport; thence crosses through a meadow and turns a high rock-bluff by a deep cut and a reduced section of 45 feet width, (see profile-sheet No. 5, section at 1135,) and descends by a plane 70 feet high to an old bed of the creek lying against a high bluff, where for a distance of nearly 4,000 feet the canal would be formed by a tow-path embankment built on the surface of the natural bank on the left of this old channel, the bluff forming the opposite slope. The creek will be confined to its proper channel by a guard-bank or dam to be built near the foot of the plane, which will also turn a small stream into the main creek. At this place a feed-culvert is provided to take water from the pool of the dam just referred to. This level continues through low farm-lands to plane No. 15, which is 55 feet high, the length of the level being 1.54 miles. Plane No. 15 descends into the bed of the stream, which is followed for a distance of 3,200 feet, after which the line leads off over low farming-lands. (See profile-sheet No. 6.) At this place a new channel is to be excavated to the left of the present one, and the stream is to be turned into it by a dam in which are to be put feed-gates as on the preceding level, the tow-path being on top of a guard-embankment. Another level, a plane 46 feet high, and a level with a lock of 8 feet lift, bring the canal into the mill-dam at Cook's Mill Station, (Pittsburgh and Connellsville Railroad.) Here, again, the main bed of the stream is to be taken for the canal, and a new channel provided for the creek, which re-enters the old channel just below the following lock of 8 feet lift. This lock is to be placed at the end of the old dam, and by its use the grade-line is brought low enough to pass the canal under the south span of the railroad-bridge at a depth of 18 feet below the bridge-chords. From the second lock until the line turns to the right and away from the bed of the creek a strong and high guard-embankment is to be made to keep the floods out of the canal. (See profile of line passing under railroad-bridge and section of canal under the bridge. Profile-sheet No. 6, and appendix-sheet I.) Feed-gates are provided for use in the dam, turning the creek into the new channel.

The four spans of the railroad-bridge at this place provide so great an excess of water-way for the creek that no possible damage can accrue by passing the canal under the end span as proposed. The guard-embankment is to be protected by a facing of stone on the outside slope to prevent abrasion by high water in the creek.

ESTIMATE.

240,240 cubic yards earth-excavation, at 20 cents	$48,048 00
49,195 cubic yards rock-excavation, (solid,) at $1	49,195 00
65,120 cubic yards channel-excavation, at 25 cents	16,280 00
132,750 cubic yards embankment, (borrowed,) at 30 cents	39,825 00
650 cubic yards culvert-masonry, at $6	3,900 00
220 cubic yards paving culverts, at $2.50	550 00
600 cubic yards slope-protection, at $1.50	900 00
150 cubic yards masonry to protect railroad-abutment, at $6	900 00
Plane No. 14, 70 feet high	43,115 00
Plane No. 15, 55 feet high	46,929 00
Plane No. 16, 46 feet high	42,878 00
Two locks of 8 feet lift, on piles	54,500 00
House for lock-tender	1,250 00
Three drainage-sluices and waste-weirs	8,400 00
Three feed-gates at three places	6,000 00
Two county-road bridges, (Bridgeport and Devore's)	3,600 00
Two farm-road crossings	3,000 00
Farm-road crossing at plane No. 14	30 00
Ninety-four acres land-damage, at $40	3,760 00
Special damages in Bridgeport	8,750 00
Engineering superintendence	5,000 00
	386,810 00

COOK'S MILLS TO GUARD-LOCK IN CUMBERLAND, 8.54 MILES.

Having brought the line of the canal down to the bed of the valley to cross under the railroad-bridge at Cook's Mills, the canal thence lies in the flat lowlands of the valley all the way to the Narrows, and (except at one place) further use of planes is unnecessary and undesirable. In consideration of the fact that the Will's Creek slope of the canal must be mainly fed from the summit-level, a uniform lift of 8 feet has been given to the locks.

Leaving the railroad bridge at Cook's Mills the line of the canal turns from the creek into the bottom-lands between the railroad and the creek, and crosses Gladden's Run at so low a grade as to necessitate the reception of that stream into the canal. At a distance of 1½ miles from the railroad bridge the canal again enters the bed of the stream, in order to pass under the bridge of the Bedford Branch Railroad, near Ellerslie, in the same general manner as at the Pittsburgh and Connellsville Railroad bridge. At this place another span must be added to the bridge for the use of the canal. A new channel is to be made for the creek to the left, with a dam and feed-gates as at the upper bridge. (See appendix-sheet K.)

From the railroad bridge at Ellerslie the line of the canal lies through low bottom-lands in a long cut averaging quite nearly the full depth of the canal, 9 feet. (See profile-sheet No. 7.)

The line now lies between the railroad and the creek, crossing the mouth of Jennings's Run by an aqueduct of 80 feet span, and placed at the same elevation as the adjacent railroad bridge. It continues on favorable ground, crossing Will's Creek by the side of the railroad bridge, just above the Narrows. (See appendix-sheet L.)

At the mouth of Jennings's Run there is room for both the creek and the canal between the railroad and the rock point on the opposite side of the creek. The grade-line of the canal is brought down to the bed of the creek at the Eckhart Branch viaduct by a plane 32 feet high, which passes under the Pittsburgh and Connellsville Railroad. The object of using a plane at this place is to enable the canal to pass under the Eckhart Branch Railroad; this will necessitate an additional bridge-span 80 feet long to pass the railroad over the canal. (See profile-sheet No. 8, section at 1723.)

The problem of locating the canal between Bridgeport and Cumberland is practically and satisfactorily solved by passing the canal under the railroad bridges at Cook's Mills and Ellerslie, and then bringing it along between the railroads and the creek, and passing it under the Eckhart Branch viaduct so as to occupy the left or east side of the bed of the creek in the Narrows. This is done by excavating the bank-slopes of the creek out to the National Road on the right and to the railrood on the left, supporting those roads by retaining-walls, and by separating the creek and canal by a division-wall of masonry. (See profile-sheets Nos. 8 and 9, and sections, and special maps of The Narrows.) Three detailed sheets of the Narrows have been made, one of which gives the contour-lines between the National Road and the railroads, and the other to show the proposed location of the canal from Braddock's Run through the Narrows and into the city of Cumberland. They also indicate the changes that should be made in roads and bridges in order to admit of this location.

ESTIMATE.

662,100 cubic yards earth-excavation, at 30 cents	$198,630 00
176,430 cubic yards rock-excavation, (in Narrows,) at $1.20	211,716 00
72,210 cubic yards channel-excavation, (to be put into guard-bank,) at 30 cents	21,663 00
312,700 cubic yards embankment, (borrowed,) at 35 cents	109,445 00
6,000 cubic yards filling between locks and guard-wall, at 25 cents	1,500 00
Aqueducts:	
2,050 cubic yards arch-masonry, at $15	30,750 00
3,400 cubic yards pier and sidewall masonry, at $12.50	42,500 00
3,895 cubic yards backing and wings, at $10	38,950 00
1,200 cubic yards rock-excavation for foundations, at $1.50	1,800 00
Contingencies of aqueducts, 10 per cent	11,400 00
1,630 cubic yards culvert-masonry, at $8	13,040 00
68,800 cubic yards retaining-wall, to support railroad and National Road in enlarging bed of creek, at $6	418,800 00
11,600 cubic yards slope-wall for tow-path, at $2.50	29,000 00
73,000 cubic yards guard-wall, (between creek and canal,) at $8	584,000 00
16 locks, 5, 6, and 8 feet lift	371,445 00
Plane, 32 feet high	33,842 00
Howe truss, 80 feet span, at Ellerslie, to pass canal under railroad, at $25	2,000 00
300 cubic yards masonry for bridge, at $10	3,000 00
Foundations	500 00
Bridge for railroad over plane, 60 feet span, with masonry	9,500 00
Iron bridge at Eckhart Branch Railroad, 85 feet span, at $50	4,250 00

750 cubic yards abutment masonry for bridge, at $10	$7,500 00
1,500 cubic yards earth-excavation for foundation, at $30	450 00
Filling behind abutment and relaying track	150 00
Tearing down National Road viaduct	1,000 00
New iron bridge for National Road—1 span 100 feet, 1 span 80 feet=180 feet, at $25	4,500 00
150 cubic yards abutment masonry, at $10	1,500 00
45,900 cubic yards embankment, (change of National Road,) at 12½ cents	5,737 50
1,000 cubic yards macadamizing, at $2.50	2,500 00
Construction of tow-path and damage to property in Cumberland	10,000 00
Six drainage-sluices and waste-weirs	16,800 00
Eight county and farm-road bridges	14,450 00
One hundred and twenty acres land-damages, at $50	6,000 00
Engineering superintendence	12,000 00
	2,220,318 50

WESTWARD FROM SUMMIT.—FROM END OF SUMMIT-LEVEL AT MEYERSDALE TO GARRETT, 4.39 MILES.

There are two locks of 6 feet lift each, so that the demand for feed-water from the summit-level may be as light as practicable until the surplus flow of Castleman River can again be used, which is done at the county-road bridge, two miles below Meyersdale. The arrangement of two locks of 6 feet lift brings the grade of the canal to a convenient height above the bed of the river at the bridge to allow the admission of feed-water from a reservoir to be made here, and also to a proper height to be carried across the river, about 3,000 feet farther on, by an aqueduct of three spans, of 50 feet each, with rises of 7 feet. There is heavy side-slope excavation just before reaching the second lock, (explained by cross-section at station 65, profile-sheet No. 10.) The tow-path embankment is placed in the bed of the river, and protected by a stone facing. The section at station 56 explains how the stream is occupied here, and a new channel cut for the river to the left. A portion of these protected slopes would be covered by the back-water of the reservoir-pool. From the second lock to Garrett are two long levels, one of 2 miles and the other 1.44 miles, and two locks, one of 11 feet and the other of 8 feet lift. The ground is very favorable for the location, as seen by the profile.

ESTIMATE.

249,370 cubic yards earth-excavation, at 20 cents	$49,874 00
120,860 cubic yards rock-excavation, at $1	120,860 00
5,550 cubic yards channel-excavation, at 25 cents	1,387 50
226,550 cubic yards embankment, (borrowed,) at 30 cents	67,965 00
Aqueduct:	
1,190 cubic yards arch-masonry, at $15	17,850 00
3,260 cubic yards piers and side-wall masonry, at $12.50	40,750 00
1,790 cubic yards backing and wings, at $10	17,900 00
500 cubic yards excavation for foundation, at 50 cents	250 00
Foundation platforms	1,500 00
Contingencies on aqueduct, 10 per cent	7,825 00
160 cubic yards culvert-arch masonry, at $12.50	2,000 00
600 cubic yards culvert-masonry, at $8	4,800 00
180 cubic yards culvert-paving, at $2.50	450 00
1,500 cubic yards slope-protection, at $1.50	2,250 00
Lock of 6 feet lift, on rock	16,730 00
Lock of 11 feet lift, on rock	29,836 00
Lock of 8 feet lift, on rock	22,134 00
Three drainage-sluices and waste-weirs	8,400 00
Dam and feed-culvert	22,500 00
County-road bridge	2,000 00
Four farm-road bridges	6,000 00
One and a half miles grubbing and clearing, at $400	600 00
One hundred acres land-damage, at $50	5,000 00
Engineering superintendence	5,000 00
	453,861 50

GARRETT TO MINERAL POINT, 7.75 MILES.

Feed-water will again be taken into the level just below the lock at Garrett by means of a dam and the usual feed-culverts. In this manner we can utilize the available discharge of Buffalo Creek, a considerable stream emptying into the river at Garrett, and also of Blue Lick Creek, which empties into the river just below the aqueduct.

A large stream is crossed opposite Garrett, requiring an arch-culvert of 20 feet span.

The first level, 2.56 miles long, is terminated by a plane 54 feet high. At about the middle of this level, and again just before coming to the plane, steep rock-bluffs are encountered. The character of construction is explained by sections on profile-sheet No. 11. Two lines were surveyed on the last half of this level, and the one lying the higher on the hill-side was adopted. From the plane to Mineral Point the location is generally a good one on side-hill slopes and flat lands, encountering a rock-bluff just opposite Mineral Point.

There are no considerable streams crossed on this section; on the contrary, there is a notable absence of large creeks on the left side of the river between Meyersdale and Confluence. Cox's Creek is quite a large tributary, entering the river from the right hand at Mineral Point.

ESTIMATE.

706,180 cubic yards earth-excavation, at 20 cents	$141,236 00
150,100 cubic yards rock-excavation, at $1	150,100 00
779,680 cubic yards embankment, (borrowed,) at 30 cents	233,904 00
1,046 cubic yards culvert-arch masonry, at $12.50	13,075 00
1,027 cubic yards culvert-masonry, at $8	13,016 00
150 cubic yards culvert-paving, at $2.50	375 00
Foundations of culverts	4,800 00
5,655 cubic yards slope-protection, at $1.50	8,482 50
Plane No. 1, (west,) 54 feet high	46,318 00
Four locks of 10 feet lift, on rock	110,160 00
Two locks of 12 feet lift, on rock	65,890 00
Seven drainage-sluices and waste-weirs	19,600 00
Dam and feed-culvert at Garrett	22,500 00
One State and county road bridge	2,000 00
Four farm-road bridges	5,300 00
Seven miles grubbing and clearing, at $400	2,800 00
Sixty acres land-damage, at $20	1,200 00
Engineering superintendence	8,000 00
	848,756 50

MINERAL POINT TO CASSELMAN, 3.2 MILES.

This section is over rough and rocky ground. There are four levels, with three locks of 12 feet lift and a plane 38 feet high just above Casselman. Two of the levels are more than a mile in length each. For about one-half of this section the slope of the tow-path reaches down to the river, and is to be protected with stone.

The water of Cox's Creek is to be utilized by a dam and feed-valves to feed into the level next below Mineral Point.

ESTIMATE.

169,400 cubic yards earth-excavation, at 20 cents	$33,880 00
85,500 cubic yards rock-excavation, at $1	85,500 00
111,350 cubic yards embankment, (borrowed,) at 30 cents	33,405 00
230 cubic yards culvert-arch masonry, at $12.50	2,875 00
330 cubic yards culvert-masonry, at $8	2,640 00
130 cubic yards culvert-paving, at $2.50	325 00
4,100 cubic yards slope-protection, at $1.50	6,150 00
Three locks of 12 feet lift each, (on rock)	98,835 00
Plane No. 2, (west,) 38 feet high	34,450 00
Three drainage-sluices and waste-weirs	8,400 00
Dam and feed-culverts at Mineral Point	25,000 00
State-road bridge at Mineral Point	1,800 00
County-road bridge at Middle Fork	1,500 00
Two miles grubbing and clearing, at $400	800 00
Sixteen acres land damage, at $30	480 00
Engineering superintendence	3,000 00
	339,040 00

CASSELMAN TO PINKERTON TUNNEL, 4.5 MILES.

The profile and sections sufficiently explain the character of this division. There are six levels with four locks of 16 feet lift and two of 14 feet lift. Forge Creek is crossed by an arch-span of 20 feet. The general character of the location is good.

ESTIMATE.

150,190 cubic yards earth-excavation, at 20 cents	$30,038 00
411,160 cubic yards embankment, (borrowed,) at 30 cents	123,348 00
321 cubic yards culvert-arch masonry, at $12.50	4,012 50
468 cubic yards culvert-masonry, at $8	3,744 00
355 cubic yards culvert-paving, at $2.50	887 50
5,630 cubic yards slope-protection, at $1.50	8,445 00
Two locks of 14 feet lift, (on rock)	76,700 00
Four locks of 16 feet lift, (on rock)	175,020 00
Six drainage-sluices and waste-weirs	16,800 00
County-road bridge (at Forge Bridge)	1,800 00
Three farm-road bridges	4,500 00
One and one-quarter miles grubbing and clearing, at $400	500 00
Sixty acres land-damages, at $20	1,200 00
Engineering superintendence	4,500 00
	451,495 00

PINKERTON TUNNEL TO CONFLUENCE, 11.44 MILES.

Although the profile shows this section to be laid on very rough ground, yet the quantities are not excessively large. All along the Casselman and Youghiogheny section of the canal the line has been purposely laid so that on the side-hill slopes the excavation on the left hand would nearly balance the embankment on the right. When rock-bluffs have been encountered the line has been taken boldly through them, but deep embankments have generally been avoided. Thus far, the river has not had many abrupt bends, and the line has not been notably crooked, but on this section the river is very crooked and in some places remarkably narrow. The great bend opposite Pinkerton tunnel is 10,500 feet long, measured by the left bank of the river, between points that are but 2,500 feet apart on a straight line. Our survey followed the bend of the river in order to determine its length and character, but there was not time enough to compare this line with the direct line across the bend, which would necessitate a tunnel and two aqueducts. The estimates have therefore been made for the route along the river-bank. The general character of this section is rough, and the fall more rapid than elsewhere on the Casselman slope of the canal. There are fourteen levels of an average length of a little more than half a mile, one of them terminating in a plane, and the others in locks of 16 feet lift. The line is laid across the river just below Brooke tunnel, (where the railroad leaves the river,) in order to occupy the more favorable ground of the right bank, and also to avoid some very difficult bluffs on the left bank, and the long bend at Harnedsville. At this village a plane has been located in order to avoid the great number of locks which otherwise would be necessary to overcome the fall. The aqueduct near Brooke tunnel has five arches of 50 feet span each, with 7 feet rise.

Harnedsville is reached by a level 2⅛ miles long, terminating in a plane 38 feet high. Thence to Confluence are two levels 1⅜ miles long, a lock of 14 feet lift, and one of 10 feet lift. Arrangements are made to take feed-water in the usual manner from the river near Shoo-Fly tunnel, (Pittsburgh and Connellsville Railroad.)

ESTIMATE.

593,590 cubic yards earth-excavation, at 20 cents	$118,718 00
23,000 cubic yards rock-excavation, at $1	23,000 00
874,270 cubic yards embankment, (borrowed,) at 30 cents	262,281 00
Aqueduct near Brooke tunnel, Pittsburgh and Connellsville Railroad:	
1,980 cubic yards arch-masonry, at $15	29,700 00
5,210 cubic yards piers and side-wall masonry, at $12.50	65,125 00
2,440 cubic yards backing and wing-wall masonry, at $10	24,400 00
Foundations, excavation, &c	1,500 00
Contingencies of aqueduct, 10 per cent	12,072 50
190 cubic yards culvert-arch masonry, at $12.50	2,375 00
268 cubic yards culvert-masonry, at $8	2,144 00
210 cubic yards culvert-paving, at $2.50	525 00
8,730 cubic yards slope-protection, at $1.50	13,095 00
Fifteen locks—2 of 10 feet lift, 1 of 12 feet lift, 12 of 16 feet lift	620,300 00
Plane, 36 feet high, and one 38 feet high	75,950 00
Sixteen drainage-sluices and waste-weirs	44,800 00
Dam and feed-culvert	25,000 00
Five State and county road bridges	10,000 00
Four farm-road bridges	6,000 00
Nine and eight-tenths miles grubbing and clearing, at $400	3,920 00
One hundred acres land-damages, at $25	2,500 00
Engineering superintendence	12,000 00
	1,355,405 50

THIRTY-SEVENTH LEVEL, (SEE APPENDIX-SHEET N,) 2.27 MILES.

The thirty-seventh level is the one at Confluence, Pa., which place was known, in the surveys of 1824, as Turkey Foot.

Owing to the changed conditions brought about by the construction of the railroad, the line of the canal must cross the Castleman River by an aqueduct of six spans of 50 feet each, and the Youghiogheny River by an aqueduct of seven spans of 50 feet each, the rises of the arches in both aqueducts being 7 feet. For the general type of these aqueducts, and for the long aqueduct at Ohio Pyle Falls, see plans of structures, sheet 6. As this drawing was the first study for these long aqueducts, some of the details, as, for example, the wing-walls, have not been fully established.

Considering it essential that a basin with wharves should be provided at Confluence, and desiring to avoid a lock on the interval between the two river-crossings, both rivers have been crossed on the same level at a height judged to be secure from high water. It is scarcely practicable to lay the grade of the canal low enough to bring in feed-water from the Youghiogheny River at this place, as that stream has but a slight inclination, and a feeder would need to be eight or ten miles in length in order to reach a point sufficiently high to deliver water into the canal with the assumed grade-line. Having provided to take in the available feed-water of the Castleman River near Fort Hill, nine miles above Confluence, provision is made to take feed-water from the Youghiogheny River at a point about three miles below Confluence. This level reaches to a distance of two miles below Confluence.

ESTIMATE.

68,630 cubic yards earth-excavation, at 20 cents	$13,726 00
22,670 cubic yards rock-excavation, at $1	22,670 00
32,440 cubic yards embankment, (borrowed,) at 30 cents	9,732 00
Castleman aqueduct:	
2,374 cubic yards arch-masonry, at $15	35,610 00
6,210 cubic yards pier and side-wall masonry, at $12.50	77,625 00
2,763 cubic yards backing and wing-wall masonry, at $10	27,630 00
Foundations to rock	2,000 00
Contingencies on aqueduct, 10 per cent	14,286 50
Youghiogheny aqueduct:	
2,770 cubic yards arch-masonry, at $15	41,550 00
7,180 cubic yards pier and side-wall masonry, at $12.50	89,750 00
3,080 cubic yards backing and wing-wall masonry, $10	30,800 00
Foundations to rock	2,500 00
Contingencies on aqueduct	16,460 00
135 cubic yards culvert-arch masonry, at $12.50	1,687 50
200 cubic yards culvert-masonry, at $8	1,600 00
145 cubic yards culvert-paving, at $2.50	362 50
Foundation of culvert, (on rock)	300 00
6,660 cubic yards retaining-wall for basin, at $6	39,960 00
Lock of 14 feet lift, (on rock)	38,350 00
One drainage-sluice and waste-weir	2,800 00
State-road bridge over basin, 80 feet span	3,000 00
Two county-road bridges	3,600 00
Two farm-road bridges	3,000 00
One-tenth mile grubbing and clearing, at $400	40 00
Forty-five acres land-damage, at $50	2,250 00
Engineering superintendence	2,275 00
	483,564 50

TWO MILES BELOW CONFLUENCE TO OHIO PYLE, 9.18 MILES.

This division begins at the first lock below Confluence and reaches to the foot of the plane at Ohio Pyle.

The first three levels of this section are each but 3,000 feet long, with one lock of 12 feet lift and two locks of 11 feet lift, the river being of rapid fall, and the mountain-slope steep and rocky. These three levels, and the following one, 3.94 miles long, show on the profile as if in excessively deep cutting, but a reference to the transverse sections made on these levels shows that the line is laid on a steep hill-side, and that the excavation and embankment quite nearly balance.

The grade-line of the fourth level is placed low for the purpose of taking feed-water from the Youghiogheny River at its upper end, at a distance of 2.37 miles below the crossing of the river at Confluence. The feeding-gates will be placed in one of the deep crevices shown on the profile at station 1871. (See profile-sheet No. 18.) Except at the bluffs of the great bend below Egypt, the ground is favorable for the remainder of the section, and the levels average one mile in length.

The last level of this division crosses the Youghiogheny River at Ohio Pyle, just above the falls and just below the State-road bridge, by an aqueduct of seven spans, of 60 feet each, with versed sines of 8 feet. The grade is 16 feet above low water and 9 feet above high water. The line here crosses the neck of the bend by a cut 15 feet in greatest depth and 700 feet in length, and descends to the river-bank by a plane 82 feet high. It at once recrosses the river by an aqueduct of three arches, of 70 feet span and 12 feet rise, at a grade-elevation of 28 feet above low water and 17 feet above high water.

It is seemingly impracticable to pass this bend in the river in any other manner than by an inclined plane. The canal could follow around the bend by using five locks of 16 feet lift or six locks of 14 feet lift, with intervals of 2,040 feet and of 1,700 feet respectively. It would, however, have to be formed on almost bare rock, by a strong retaining-wall, with but a very meager supply of clay or loam soil to form the banks. The use of a plane seems by far the better method of passing this point.

Feed-water is to be taken into the pool at the foot of the plane by a feeder leading up the river to a point at which the available flow of the stream can be turned in by a low dam, the daily flow as gauged in 1825 being 155 cubic feet per second.

ESTIMATE.

281,425 cubic yards earth-excavation, at 20 cents	$56,285	00
886,435 cubic yards rock-excavation, at $1	886,435	00
334,750 cubic yards embankment, (borrowed,) at 30 cents	100,425	00
Aqueduct at Ohio Pyle, upper crossing:		
3,022 cubic yards arch-masonry, at $15	45,330	00
5,610 cubic yards pier and side-wall masonry, at $12.50	70,125	00
3,695 cubic yards backing and wing-wall masonry, at $10	36,950	00
Foundations on bare rock	500	00
Contingencies of aqueduct	15,290	50
350 cubic yards culvert-arch masonry, at $12.50	4,375	00
250 cubic yards culvert-masonry, at $8	2,000	00
145 cubic yards culvert-paving, at $2.50	362	50
13,760 cubic yards slope-protection, at $1.50	20,640	00
2 locks of 11 feet lift, on rock	60,280	00
2 locks of 12 feet lift, on rock	65,890	00
2 locks of 16 feet lift, on rock	87,510	00
Plane 82 feet high	50,193	00
Six drainage-sluices and waste-weirs	16,800	00
State-road bridge at Ohio Pyle	25,000	00
Street-bridge to peninsula, Ohio Pyle	1,800	00
Two county-road bridges	3,000	00
Eight and one-fourth miles grubbing and clearing, at $400	3,300	00
Twenty acres land-damage, at $50	1,000	00
Engineering superintendence	9,000	00
	1,562,491	00

OHIO PYLE TO INDIAN CREEK, 9.30 MILES.

This section includes the aqueduct at the foot of the plane at Ohio Pyle. (See plans of structure, sheet No. 7.) The grade-line of this aqueduct is 28 feet above low water. There is a distance of 300 feet between the foot of the plane and the aqueduct, into which the feeder would deliver the supply of water taken at this place.

This division lies over very rough ground, covered with loose rocks, and on slopes that reach down to the water's edge; for this reason a large amount of support-wall is estimated for, the river being so narrow that its width cannot safely be lessened by embankment-slopes, even though protected by a facing of stone. (See profile-sheet No. 21, sections at 2350, 2355, 2362.) At the bluff-rock bank, at station 2641, (profile-sheet No. 22,) the river being of sufficient width, the canal is passed around the bluff by a high tow-path embankment, protected by a facing of stone. At station 2710 the canal has a contracted width in a rock section for a distance of 700 feet, adjacent to a lock which is in part to be placed in the rock. (See profile-sheet No. 22, sections at 2703 and at 2707.)

ESTIMATE.

485,165 cubic yards earth-excavation, at 20 cents	$97,033	00
490,220 cubic yards rock-excavation, at $1	490,220	00
822,670 cubic yards embankment, (borrowed,) at 35 cents	287,934	50
Aqueduct at Ohio Pyle, lower crossing:		
1,542 cubic yards arch masonry, at $15	23,130	00
2,835 cubic yards pier and side-wall masonry, at $12.50	35,437	50
2,595 cubic yards backing and wing-wall masonry, at $10	25,950	00
Foundations (on rock)	1,600	00
Contingencies of aqueduct, 10 per cent	8,611	75

1,490 cubic yards culvert-arch masonry, at $12.50	$18,625 00
2,189 cubic yards culvert-masonry, at $8	17,512 00
927 cubic yards culvert-paving, at $2.50	2,317 50
54,900 cubic yards support-wall, at $6	329,400 00
11,465 cubic yards slope-protection, at $1.50	17,197 50
One lock of 10 feet lift, on rock	27,540 00
One lock of 12 feet lift, on rock	32,945 00
One lock of 14 feet lift, on rock	38,350 00
Five locks of 16 feet lift, on rock	218,775 00
Plane 70 feet high	47,010 00
Nine drainage-sluices and waste-weirs	25,200 00
Dam and feeder at Ohio Pyle	24,845 00
Two county-road bridges	3,500 00
Eight and three-quarters miles grubbing and clearing, at $400	3,500 00
Eight acres land-damage, at $20	160 00
Engineering superintendence	9,000 00
	1,785,793 75

INDIAN CREEK TO DUNBAR CREEK, 6.48 MILES.

At Indian Creek the river widens out and forms a wide pool, and its width is not again contracted on this division, and wherever there is any bluff-rock bank the canal can be formed in the bed of the river and the embankment-slope protected, which is done at several places on this division.

Provision is made for feeding the canal just below the mouth of Indian Creek by a dam built across the river just above the island at this place. The grade-line of the canal being placed at the same elevation as the bed of the river, a dam 12 feet high will give the pool of the dam a surface 7 feet higher than the surface of the water in the canal. This place being considered a prominent point for the shipment of lumber and iron-ores, I have included in the estimates of this division a guard-lock of 16 feet lift. Including the back-water that would be formed in Indian Creek, this reservoir would, in addition, be very valuable as a harbor for boats and as a shipping point.

The canal is led into the river just above the mouth of Dunbar Creek, and just after passing under the Fayette County Branch Railroad, for which purpose a span of bridge will be required. To conform to the other bridge-structures on this branch, I have estimated for a wooden Howe truss of 80 feet clear span.

ESTIMATE.

119,230 cubic yards earth-excavation, at 20 cents	$23,846 00
235,760 cubic yards rock-excavation, at $1	235,760 00
595,130 cubic yards embankment, (borrowed,) at 35 cents	208,295 50
500 cubic yards culvert-arch masonry, at $12.50	6,250 00
750 cubic yards culvert-masonry, at $8	6,000 00
530 cubic yards culvert-paving, at $2.50	1,325 00
17,130 cubic yards slope-protection, at $1.50	25,695 00
One lock of 12 feet lift, on rock	32,945 00
One lock of 14 feet lift, on rock	38,350 60
Three locks of 16 feet lift, 2 on rock and 1 on platform	136,400 00
One lock of 16 feet lift, (Indian Creek reservoir)	48,800 00
One Howe-truss railroad-bridge, 90 feet length	2,250 00
600 cubic yards abutment-masonry for bridge, at $10	6,000 00
Foundations and excavation	1,250 00
Five drainage-sluices and waste-weirs	14,000 00
Farm-road bridge	1,500 00
Five and one-half miles grubbing and clearing, at $400	2,200 00
Twenty acres land-damage, at $50	1,000 00
Engineering superintendence	6,500 00
	798,366 50

SUMMARY OF LINE VIA WILL'S CREEK.

Summit-level		$7,957,416 50
Eastward from summit.		
East end of summit-level to Southampton level	8 miles	$1,115,152 50
Southampton level to Bridgeport	6.45 miles	1,418,323 50
Bridgeport to Cook's Mills	5.44 miles	386,810 00
Coak's Mills to Cumberland	8.54 miles	2,220,318 50
Total for	28.43 miles	5,140,604 50

Westward from summit.

Meyersdale to Garrett	4.39 miles	$453,861 50
Garrett to Mineral Point	7.75 miles	848,756 50
Mineral Point to Casselman	3.20 miles	339,040 00
Casselman to Pinkerton Tunnel	4.50 miles	451,495 00
Pinkerton Tunnel to Confluence	11.44 miles	1,355,405 50
Thirty-seventh level	2.27 miles	483,564 50
Confluence to Ohio Pyle	9.18 miles	1,562,491 00
Ohio Pyle to Indian Creek	9.30 miles	1,785,793 75
Indian Creek to Dunbar Creek	6.48 miles	798,366 50
Total for	58.51 miles	8,078,774 25

FINAL SUMMARY.

Summit-level	$7,957,416 50
East from summit-level to Cumberland	5,140 604 50
West from summit-level to Dunbar Creek	8,078,774 25
Grand total	21,176,795 25

The following table will be useful for reference:

Table of distances and elevations of various points on the line of the proposed extension of the Chesapeake and Ohio Canal, from Cumberland to Pittsburgh, by way of Will's Creek.

Miles from Cumberland.	Place.	Elevation above low-tide.	Remarks.
		Feet.	
0.00	Cumberland, guard-lock of Chesapeake and Ohio Canal.	601.50	Top of miter-sill.
1.29	East end of "Narrows" of Will's Creek.	621.50	Surface of water in Will's Creek.
2.33	Braddock's Run	644.00	Do.
4.13	Jennings's Run	694.00	Do.
7.73	Gladden's Run	740.00	Do.
13.98	Bridgeport, Pa	915.00	Railroad-track at depot.
15.87	Gooseberry Run	1,050.00	Surface of Will's Creek 200 feet above.
19.56	Fairhope Station	1,332.56	Surface of Will's Creek 500 feet above bridge.
22.50	Southampton	1,528.32	Surface of Will's Creek.
25.10	Laurel Run	1,673.46	Do.
29.98	Bowman's Run	1,960.00	Do.
	Summit-level	1,944.00	Bottom of canal.
	Summit of Pittsburgh and Connellsville Railroad grade.	2,286.00	1½ miles south of canal-line.
32.02	Highest point over canal-tunnel	2,868.00	
35.47	Meyersdale, mouth of Flaugherty	1,934.40	Surface of Castleman River.
37.52	Blue Lick Run	1,922.00	Do.
38.98	Yoder's Station	1,912.50	Do.
39.83	Garrett Station, mouth of Buffalo Creek	1,910.00	Do.
47.22	Mineral Point, mouth of Cox's Creek	1,790.00	200 feet above.
47.69	Mineral Point, Shaff's Bridge	1,787.00	Surface of Castleman River.
51.38	Castleman Station	1,717.50	Do.
53.56	Forge Bridge	1,667.80	Do.
55.45	Pinkerton Station	1,625.20	Surface of Castleman River 2,000 feet above.
59.74	Fort Hill, county-bridge	1,474.30	Surface of Castleman River under bridge.
65.17	Harnedsville	1,343.60	Surface of Castleman River 1,300 feet below White's Creek.
67.92	Junction of Castleman and Youghiogheny at Confluence.	1,312.90	Surface of Youghiogheny at junction.
78.09	Ohio Pyle	1,206.66	Surface of Youghiogheny 200 feet below bridge.
83.33	Stewarton Station	1,003.34	Surface of Youghiogheny.
87.56	Indian Creek	940.17	Do.
94.15	Dunbar Creek	865.09	Do.
95.04	Connellsville, suspension-bridge	858.27	Do.
97.97	Broad Ford Station	838.90	Do.
99.87	Sedgwick Station	829.25	Do.
101.10	Dawson, mouth of Dickinson Run	827.40	Do.
102.76	Laurel Station, mouth of Laurel Run	819.50	Do.
105.04	Virgin Run, mouth of	805.48	Do.
108.20	Layton, mouth of Washington's Run	781.91	Do.
112.33	Jacob's Creek	764.85	Do.
116.06	Port Royal	750.25	Surface of Youghiogheny above dam.
120.60	West Newton	735.68	Surface of Youghiogheny under county-bridge.

SURVEY UP THE NORTH BRANCH OF THE POTOMAC.

The first survey of this route was made in 1823 by Maj. J. J. Abert, Corps of Topographical Engineers, as a part of the route for carrying the canal across the mountains to the Youghiogheny by way of Savage River and Deep Creek. A subsequent examination of the Will's Creek route showing that route to be much the more favorable of the two, it has always been considered *the* route for taking the canal over the mountains. The section from Cumberland to Savage River has, however, been generally thought a desirable extension of the canal in order to reach the coal-fields of George's Creek, even though the main canal were built on the Will's Creek route.

The present survey was begun on the 16th of August, at the mouth of Savage River, and completed at Cumberland on the 24th of October. An approximate location of the line of the canal has been made along the left bank of the North Branch, occasionally occupying the bed of the river for short distances, such occupancy of the river being caused by the contiguity of the Baltimore and Ohio Railroad, the embankment-slopes of which reach into the river at these places.

At each of the places where the bed of the river has been taken for the body of the canal, a new channel has been made for the river on the right. The general manner of doing this has been to build the tow-path embankment in the river at such a distance from the slopes of the railroad-embankments as to provide the necessary width of water-surface for the canal, and to remove enough of the opposite bank to give a proper width of channel for the river. The grade-line of the canal, which, in this report, always means its bottom, and is referred to low-tide at Georgetown, is, in all these cases, put above the ordinary surface of the river in order to economize in making the canal on the bottom-lands, on to which the grade-line reaches from the river-pools. This elevation of the grade-line does not increase the expense at these places, for the reason that, in any event, the embankment, which serves as tow-path and guard-wall, must be made high enough to protect the canal from floods, and the height thus necessitated is usually greater than would otherwise be required for the canal.

The material borrowed from the opposite bank is used to form the tow-path embankment; but, as a rule, the material needed for this purpose is greater than that required for enlarging the channel, and then the additional quantity is obtained by a further widening of the river-channel. In these cases the tow-path embankments are from 15 to 20 feet high, and their river-slopes are protected from injury by a facing of stone. The river-bed is occupied in this manner at fourteen places, which will be described in the explanations of the estimates.

The distance from Cumberland to the mouth of Savage River is 30½ miles, but the canal will not be so long as this, for the reason that it enters the river at the head of the back-water from the reservoir-pool which feeds the completed canal at Cumberland. The canal is thus shortened 1.8 miles. A much shorter line could have been had by crossing the river seven or eight times with aqueducts, but the expense of construction would have been greatly increased.

Aqueducts are the weak points in a canal, and as their number is increased, the chances of serious injury from floods are increased in the same proportion. When aqueducts are used to carry the canal over the main streams, they must be built high enough to put the body of the canal above the highest floods; this generally entails a heavy expense in the construction of high embankments to support the canal across the low grounds to and from the aqueducts. From the nature of these high embankments, the loss through them by seepage is greater than at other places in the canal.

If many aqueducts are used on the line of the canal, its bottom is kept at a higher elevation with reference to the general surface of the valley in which it lies than would otherwise be necessary, and this elevation of the water-prism of the canal increases the seepage through the banks, and entails frequent injury by leaks and breaks.

If the line of the canal can be kept continuously on one side of the main stream followed, it can be laid as low as may be desirable, and, except when a lateral stream or valley is to be crossed, can generally be formed by excavating the depth of the canal below the surface of the valley, it being generally possible to arrange the locks for this purpose. This method of construction confines the water of the canal within banks of undisturbed material, and the losses by breaks and leaks are considerably decreased. The water of the canal being at a low height above the average surface of the adjacent river, the loss by filtration may be also said to be reduced to a minimum. When the canal is thus laid on a low-grade line, many of the lateral streams are crossed so near the level of their beds that they may be made to empty directly into the canal, which in such cases generally forms a pool of back-water at their mouths, by which the force of their currents, when in flood, is broken, and in which are deposited the wash and detritus brought down from above, so that they do not reach the bed of the canal. In this manner these streams may contribute considerable quantities of water toward replenishing the ordinary losses of the canal.

The larger lateral streams, generally having high banks with considerable width between them, cannot, as a rule, be thus crossed, and culverts or aqueducts must be used to carry the canal over them, thus causing weak points in the line. When the line of the canal can be laid on a grade line below the natural surface, as just described, the positions of the locks are generally indicated by the natural features of the ground, and they can usually be placed on secure foundations.

These considerations, with others of minor importance, are here indicated as those which controlled the location of the line of the canal made by this survey.

ESTIMATE OF COST OF THE EXTENSION TO SAVAGE RIVER.

This extension is planned to have the same dimensions as the completed canal, which are 60 feet width of water-surface, 32 feet of bottom width, and 6 feet depth of water. The locks are 100 feet long between the gates and 15 feet wide, and have a uniform lift of 8 feet.

A few of the locks will be founded on solid rock, and the others will be built on platforms of two courses of squared timbers covered with a flooring of plank 2½ inches in thickness, or on concrete, or a combination of the two methods will be used. A lock of the ordinary type is estimated to cost $19,900 when built on a rock foundation, and $23,750 when built on timber, including in each case a house for the lock-tender, with 10 per cent. profit to contractor. Waste-weirs to be built in combination with drainage-sluices are estimated for on appropriate levels. The drainage-sluice is formed by a wall of masonry of 4 feet thickness in which are two openings 4 by 4 feet, to be closed with iron gates sliding in iron guides, and raised by means of ratchet and pinions. This drainage-sluice is on the same plan as proposed for the Will's Creek extension. The waste-weir is to be built on each side of this sluice so as to provide a width of overflow of 100 feet, and it is to be well paved with stone to prevent wash. The cost of this structure is estimated at $2,500. Substantial bridges are estimated for to pass State, county, and farm roads over the canal. They are to be made of wood and supported on stone abutments. The clear width between the abutment on the berm and the tow-path is 45 feet. Wherever these bridges could be put over the tail-bay of a lock they have been so placed for considerations of economy in the length of span and quantity of masonry. Their cost varies with their localities and their positions in relation to the locks.

There is a notable absence of large streams entering the river from the left side, there being none that cannot be passed by ordinary culverts of from 6 to 12 feet span. George's Creek is received into the pool made by a dam in the river at Piedmont.

Wherever the line of the canal has been laid on flat-bottom lands, the grade of the bottom of the canal has been put low enough to keep the canal mainly in excavation. The economic depth of the grade-line below the surface, that the excavation may furnish earth enough to form the banks, is about 3½ feet. If the canal is cut below the surface to a less depth than 3½ feet, the deficiency in the quantity needed to form the tow-path and berm embankments must be borrowed from adjacent lands, which may cause considerable damage, while, on the other hand, if the grade-line is at a greater depth below the surface than 3½ feet, the surplus earth may be used to advantage in making the tow-path higher above the water-surface than the 2 feet assumed in the normal cross-section, thus securing more favorable conditions of draught for the animals towing the boats. If the canal is placed all in cutting, the conditions for holding the water will be better than when it is in part or wholly in embankment. For this reason even small embankments under the bottom grade-line have been avoided in the flat lands. (See profile-sheets Nos. 2, 4, &c.) This method results favorably in placing the locks deeper in the ground, rendering them more secure.

No provision is made for feeding the North Branch extension except at its upper end, near the mouth of Savage River. By the method of construction adopted at the mouth of Savage River, a large reservoir pool will be formed, extending about a half a mile up both the North Branch and Savage River, into which boats may enter by the feeder lock.

The line has been divided into characteristic sections the better to present the estimate.

FROM THE MOUTH OF SAVAGE RIVER TO THE LOCK JUST BELOW GEORGE'S CREEK AT PIEDMONT, 1.84 MILES.

A dam is placed across the North Branch 600 feet below the mouth of Savage River, which is to have an ordinary lock at its north end, and a high abutment with wings at the south end. This dam is to be built with a body of masonry, filled in on the upper side with rock and sand to a slope of 1 on 2½. The lock is to be high enough to act as a guard-lock when the river is in flood. (See profile-sheet No. 1, section at station 21.) The North Branch makes here so sharp a bend that it is designed to provide a new channel for it to the right of the dam, cutting off a portion of the bend. (See map, sheet No. 1.) A weir or dam will be placed at the upper end of this channel, with its crest at about the same elevation as the crest of the dam in the stream below, so that in the ordinary stages of the river its entire flow will pass down to the lock for use, but when the river is in flood its surplus water will flow over the weir into the new channel, and the dam and lock will be relieved of the pressure and danger of injury from this surplus. The surplus of the Savage River when it is in flood will, however, pass over the dam at the lock. Hence the necessity of a guard-lock at the dam. A guard-bank will be formed between the new channel and the river from the material taken from the new channel. Its cost will be covered by the price of the excavation of the new channel.

From the dam to the head of the race-way leading to the pool of Hon. H. G. Davis's saw-mills, a distance of 2,900 feet, the canal is formed by building the tow-path embankment in the bed of the river, which is shallow, and by confining the canal against the slope of the hill on the left bank. This embankment is high enough to protect the canal from overflow by river-floods, and is to be protected by a stone facing. The greater part of the material for this embankment will be taken from the new channel, to be made on the opposite side of the river to provide room for floods.

Lock No. 2 is at the head of the race-way, and No. 3 is at the lower end of the pool. Between these locks the canal occupies the race-way and a part of the pool used for floating logs to the saw-mill. The portion of the canal in the pool is to be formed by building an embankment for the tow-path, and confining the canal against the opposite slope of the hill. (See profile-sheet No 1.)

There is a "bear-trap" gate at the head of this race-way to regulate the feeding of water into the pool. In consequence of this occupancy of the race-way and pool, and of the disturbance of the boom in the river at the head of the race-way, a new race-way and an enlargement of the pond must be made to repair the damage. A low dam should be made across the river just below the head of the new race-way, the more effectually to restore the conditions disturbed by the construction of the canal. The material excavated in enlarging the pool will be needed to form the tow-path.

Thence for a distance of 2,000 feet the canal lies on favorable ground, and drops into the river just above Piedmont. Lock No. 5 is placed in the river-bank, and through it boats will pass into the river. An embankment extending to the lock from the lower end of the island just above serves as a guard-bank and tow-path. This embankment will be continued up-stream along the island, and cross to the left bank of the river, in order to protect the canal-bank from injury during floods. From lock No. 5 to lock No. 6, which is at the road-bridge between Piedmont and Westernport, the river is occupied by the canal. It does not seem possible satisfactorily to avoid this occupancy of the river. The line could be carried over the river from near lock No. 4, and thence through Piedmont, crossing the river again just below the town, and after traversing the island crossing the other channel of the river to the left bank. This route would require three expensive aqueducts, and entail heavy land and property damage in Piedmont, besides seriously interfering with the property and operations of the Baltimore and Ohio Railroad.

The plan recommended for passing Piedmont is to occupy the river to the Westernport bridge, making a pool by a low dam, the position of which is shown on sheet No. 1; this bridge would have to be removed and placed over the dam, so that the Westernport end would cross the tail-bay of lock No. 6. The track and bridge of the Cumberland and Pennsylvania Railroad, which crosses the river just above the Westernport bridge, being too low to permit boats to pass under it, (see sketch of bridge on profile-sheet No. 1,) could be changed in location to cross the canal and river just below lock No. 6, by bringing the road along the foot of the slope on the east side of Westernport, and laying it through that part of Piedmont east of Ashfield street. Lock No. 6 would be built as a guard-lock, and its walls could bear the road-bridge, but not the railroad-bridge, for the reason that the shocks of passing trains would injure the walls of the lock. The cost of changing the railroad location and removing the bridges would not be very great, nor the property damages excessive, unless the Cumberland and Pennsylvania Railroad should be adjudged heavy damages. The damage to this railroad would be very small compared with that which would be done to the Baltimore and Ohio Railroad if the alternative line through Piedmont were chosen.

A tow-path embankment is to be made on the left side of the river against the slope of the hill, between lock No. 5 and the road-bridge opposite the Baltimore and Ohio Railroad shops. A tow-path crossing-bridge would be put across the tail-bay of lock No. 5, to bring the tow-path from the right to the left side of the canal, and a tow-path bridge added on the upper side of the road-bridge just below, so as to reach the Piedmont side of the river, it being very costly to pass along the left bank between the road-bridge and the railroad-bridge. The tow-path will follow along the right bank of the river to the new position of the Westernport bridge, and then cross the river along the upper side of the bridge to lock No. 6, where it would again change to the right side of the lock, and thence follow the embankment to be built in the channel below to form the canal between it and the natural bank.

This plan for passing Piedmont establishes a much better condition for operating the canal than could be attained by passing through the town by the side of the Baltimore and Ohio Railroad. Referring to the map and profile, it will be observed that the reference of the low water of the river opposite lock No. 4 is 921.56. To cross this by an aqueduct would require the grade of the bottom of the canal to be from 16 to 18 feet higher, making its reference about 939.00. To make this crossing the canal would be carried over on the level that begins at lock No. 2, which has for its bottom reference 939.00. This is 6 feet higher than the surface at station 60. (See profile-sheet No. 1.) Assuming the reference of the river at the crossing below the town to be 902.00, which is that of the corresponding point at station 115, (see map No. 1,) and allowing as before an addition of 18 feet for the reference of the grade of the canal, we have for its reference 920.00. This difference of grade between the two crossings would require two locks of 9½ feet lift each, to be placed in the town. The first of these locks, which would be No. 3 of the canal, could be placed in continuation of the aqueduct at the upper crossing, and the other (No. 4) at the upper end of the lower aqueduct, and the aqueducts could then be narrowed to a width of 18 or 20 feet.

To carry the canal across the channel on the left side of the island at the same relative elevation with the river as before, a lock (No. 5) would be required on the island. The crossing of this channel by an aqueduct can be avoided by closing it by a high dam at the head of the island, and carrying the canal across by an embankment. This would lower the grade-line so as to allow two locks (Nos. 5 and 6) to be placed on the island. The reference of the bottom of the canal below lock No. 6, at station 130, would be 802.00, locks Nos. 5 and 6 being each of 8 feet lift. An additional lock would be needed between stations 130 and 160 to bring the grade of the canal to the best condition for cheap construction below lock No. 9, but this would reduce the present well-arranged intervals between locks 6, 7, 8, and 9.

The railroad-tracks in Piedmont are very nearly, if not quite, on the natural surface, and assuming lock No. 3 to be placed at the end of the upper aqueduct, the depth of the bottom of the canal would be not more than three or four feet below the surface, or if a 10-foot lift-lock were used, as is shown for lock No. 3 on the profile, the depth would be from five to six feet below the surface. It is thus apparent that the canal would have to be provided with turning-bridges to accommodate so many railroad-tracks and street-crossings as would be required to serve the railroad companies and the town. As all the space between the railroad-shops and the main line of the Baltimore and Ohio Railroad is covered with tracks, this location may certainly be considered impracticable.

ESTIMATE.

The section from the mouth of Savage River to lock No. 6, a distance of 1.84 miles, is estimated to cost as follows:

Lock and dam near mouth of Savage River, with contingencies	$58,950 00
Dam at upper end of new channel for turning the river, (North Branch)	17,650 00
66,565 cubic yards of tow-path embankment between lock No. 2 and dam, at 50 cents	33,282 50
22,220 cublic yards of channel-excavation, at 30 cents	6,666 00
6,875 cubic yards of slope-protection above lock No. 2, at $1.50	10,312 50
112,770 cubic yards of embankment, tow-path, &c., at 50 cents	56,385 00
51,900 cubic yards of earth-excavation, at 20 cents	10,380 00
2,000 cubic yards of rock-excavation, at $1	2,000 00
8,750 cubic yards of slope-protection, at $2.25	19,687 50
5 locks, No. 6 being a guard-lock	126,000 00
Drainage-sluice and waste-weir	2,500 00
Dam across river, crib-work at Davis Mills	5,000 00
Road-bridge over lock No. 3	700 00
Tow-path bridge at lock No. 5	300 00
Tow-path bridge added to road-bridge	500 00
Dam at Piedmont	23,900 00
Changing line of Cumberland and Pennsylvania Railroad and moving bridge to lock No. 6	23,000 00
Moving Piedmont and Westernport bridge	4,350 00
Damages in Piedmont on account of Cumberland and Pennsylvania Railroad	10,000 00
Tow-path bridge on upper side of road-bridge	1,250 00
Special damages in Piedmont	3,000 00
Special damages in Westernport	2,500 00
Total for 1.84 miles	418,313 50
Average cost per mile	227,344 29

FROM WESTERNPORT BRIDGE TO LOCK NO. 9, 1.10 MILES.

The canal is continued below lock No. 6, by making a tow-path and guard-embankment from the end of the lock to the island, and continuing this embankment along the left side of the island, occupying the left channel for the canal. This would be much less expensive than building the tow-path in the bed of the channel to form the canal against the left bank, which is high and steep. (See section 140, profile-sheet No. 2.) The tow-path and guard-embankment would now lie in the bed of the river, which is shallow from the island to the head of the old mill-race at station 160, where the canal-line leaves the river, turning to the left on to flat bottom-land.

ESTIMATE.

This section will cost as follows:

61,300 cubic yards embankment, (tow-path,) at 50 cents	$30,650 00
5,760 cubic yards slope-protection, at $2	11,520 00
Three locks on rock foundation, at $20,000	60,000 00
Three houses for lock-keepers *	2,400 00
One drainage-sluice and waste-weir	2,500 00
Total for 1.10 miles	107,070 00
Average cost per mile	97,336 36

If instead of extending the canal to Savage River, Westernport (which is at the base of the George's Creek coal-field) is made its objective point, the two sections just described could be dispensed with and the canal terminated at lock No. 9. By this plan a section that is both expensive and troublesome to navigate would be avoided.

If the canal were terminated at lock No. 9, the Cumberland and Pennsylvania Railroad could be extended to the canal along the left bank of the left-hand channel, and deliver coal at the basin and wharves that would be made on the low ground just below this lock. This railroad was built in the interest of the coal-mines, and the coal-traffic is its main business. The extension of the canal to Bloomington, at the mouth of Savage River, is a matter of no importance, except as a part of the Savage River route for the extension of the canal across the mountains, on which I reported in January, 1874, unless it should be found practicable to provide an extension into the upper valley of the North Branch to the extensive coal-fields of that region. If this upper valley should, however, be improved by a railroad built to connect with the canal, then it would, in my opinion, be preferable to make this connection below Piedmont. There are, however, three coal-mining concerns in full operation above Piedmont, the Hampshire mines, the Virginia mines, and that of Mr. William A. Brydon. The first-named mines are above Bloomington, on the North Branch, the second below Bloomington, and the last is just above Bloomington on the Savage.

FROM LOCK NO. 9 TO 19, OPPOSITE KEYSER, 4.17 MILES.

For a distance of one and a quarter miles below lock No. 9, reaching to Stony Run, the line is laid over low, flat ground, most favorable for cheapness of construction. A bold rocky point is passed just below Stony Run (see profile-sheet No. 2, section at station 140) by building the tow-path in the river, as previously described, for a distance of 1,250 feet, after which the line turns to the left on level bottom-lands for a distance of 1.1 miles, with the most favorable conditions of cost in construction. The canal then lies along a slate-rock bluff, (see profile-sheet No. 2, section at station 224,) which is to be passed by a tow-path and guard-embankment for a distance of 2,000 feet; it then follows along the left bank of the river on generally favorable ground, passing occasionally along the face of short slate-rock bluffs, and now and then occupies a high-water channel of the river, with a high tow-path bank to form the canal and to guard against floods. (See section on profile-sheet No. 2.) There is no notable obstacle on this section. An alternative line, lying on higher ground to the left, was examined between stations 260 and 388. The general profile was favorable and the line was well supported, but the descent was too rapid at the lower end near Keyser, crowding the locks into very short intervals. Its outline is shown on profile-sheet No. 3. A line connecting with this higher line was run across the ridge opposite Keyser, which could have connected with the main line at station 519 by a plane, or at station 615 by locks. It did not develop any favorable conditions, the ridge being too high.

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*At other locks these houses have been included in the cost of locks.

ESTIMATE.

This section is estimated to cost as follows:

135,500 cubic yards earth-excavation, at 20 cents	$27,100	00
7,500 cubic yards rock-excavation, at $1	7,500	00
256,000 cubic yards embankment, (borrowed,) at 30 cents	76,800	00
15,500 cubic yards slope-protection, at $2.50	38,750	00
250 cubic yards arch-culvert masonry, at $10	2,500	00
Ten locks	218,250	00
Six drainage-sluices and waste-weirs	15,000	00
Four county and farm road bridges over tail-bays of locks	3,200	00
Two miles grubbing and clearing, at $300	600	00
Sixty acres land-damage, at $25	1,500	00
Total for 4.17 miles	391,200	00
Average cost per mile	93,812	94

FROM LOCK NO. 19, AT KEYSER, TO LOCK NO. 53, ONE AND ONE-EIGHTH MILES ABOVE RAWLINGS'S STATION ON THE BALTIMORE AND OHIO RAILROAD, 8.9 MILES.

For some distance above as well as below lock No. 19 the canal is formed in an old bed of the river by making the tow-path embankment on the high ground to the right, confining the water against the opposite bluff. (See profile-sheet No. 3, section at 364.) The difficult high-rock point opposite Keyser is passed by a tow-path guard-embankment to be built in the river, as shown by section at 394, profile-sheet No. 3. The canal then lies over bottom-lands, touching, however, a rock-cliff at section 439 so close to the river as to require a stone facing to the embankment (see section at 440, sheet No. 3) until the railroad-bridge is reached at station 470.

The canal is passed under this bridge by placing a lock at station 468, lowering the grade-line to the level of the river, and occupying the stream for a distance of 1,100 feet. (See section at 478, sheet No. 4.) There is room under the railroad-bridge for both canal and river, but additional water-way should be provided for the river by another span of bridge on the right. This bridge, which is known as No. 21, carries two tracks. The river-channel should be widened as shown by the brown shading on sheet 4. The line then turns to the left away from the river, and lies over bottom-lands for a distance of 2⅜ miles, with long levels and excellent conditions. (See profile-sheet No. 4, upper line.)

Below lock 26 the canal is laid alongside of the Baltimore and Ohio Railroad, partly by using a tow-path and guard-embankment and partly in cutting on a terrace. At the island near station 653 the channel to the right is widened for the river. The river is occupied here for a distance of half a mile. The line thence lies for a distance of 2 miles over fine bottom-lands, well known in this section of the country as the "Black-Oak Bottom." They average something more than half a mile in width by 2 miles in length. Profile-sheet No. 4, lower profile-line, shows how favorably these 2 miles are passed by three locks, with full-depth cuts for long distances. From station 785 to 805 the river is again occupied for the canal by a tow-path and guard-embankment in the river, the earth for which is to be taken from the opposite bank to widen the river. (See sheet No. 7 and profile-sheet No. 4, section at 800.) Thence the line lies over favorable bottom-lands for a distance of 1 mile, to the end of this section. (See profile-sheet No. 5.)

ESTIMATE.

The estimated cost of this section is as follows:

372,310 cubic yards earth-excavation, at 20 cents	$74,462	00
223,350 cubic yards embankment, (borrowed,) at 45 cents	100,507	50
73,040 cubic yards embankment, at 30 cents	21,912	00
17,485 cubic yards slope-protection, at $2.50	43,712	50
Thirteen locks of 8 feet lift, at $23,750	308,750	00
Twelve drainage-sluices and waste-weirs	30,000	00
One county-road bridge	1,500	00
Seven farm-road bridges at locks, at $800	5,600	00
Two farm-road bridges, at $1,500	3,000	00
One hundred and thirty acres of land-damages, at $50	6,500	00
Special damages	800	00
Two iron truss-bridges, spans of 85 feet, at $50	8,500	00
1,200 cubic yards bridge-masonry, at $10	12,000	00
Foundation of one abutment	4,750	00
Contingencies of bridge-work, 10 per cent	2,000	00
Total for 8.9 miles	623,994	00
Average cost per mile	70,111	68

FROM LOCK NO. 32 TO BRADY'S MILL STATION, 8.16 MILES.

Just below lock No. 32 the canal enters the bed of the river, which is occupied for a distance of 1,600 feet by means of a tow-path and guard-embankment, the rock-slope of the railroad reaching into the river. The usual widening of the channel for the river is made on the right. The line then turns to the left from the river, and lies for a distance of 4 miles over low bottom-lands, with the usual favorable conditions for economic construction. A portion of this distance is over the fine bottom at Rawlings's Station. Three or four small streams are crossed requiring culverts. (See profile-sheet No. 5, locks Nos. 32 to 36.) The canal now again takes possession of the river at the crossing of the Winchester Pike, at which place a stream is crossed requiring a culvert, and follows the railroad slope for a distance of 3,800 feet, with the usual tow-path and guard-embankment and enlargement of the river-channel on the right, and then lies in a small channel of the river close under a steep rock-bluff for a further distance of 2,500 feet, whence it turns to the left on to the bottom-lands. In the last-mentioned distance the left bank of the adjacent island is to be occupied by the tow-path embankment. (See section 1137, profile-sheet No. 5.)

The Winchester Pike (so called) is a well-graded dirt-road, crossing the river at station 1090 of the canal-line. The road formerly crossed the river by a truss-bridge, which has been destroyed, leaving the abutments in a ruined condition. The river is now crossed by fording, the road passing under the railroad-bridge at this place, which is long enough to give room for both stream and road. The grade of the canal is too low to admit of the pike being passed under it, and therefore it must be carried over the canal in the ordinary way. The railroad company has provided for permitting the road to cross its track to the bridge over the river should it be rebuilt, and the grade of the canal is low enough to admit the floor of this bridge to be put on a level with the railroad-track. Estimate is made for an additional bridge-abutment, so as to provide for a span of bridge to reach over the canal to the abutment of the old bridge.

The grade-line of the canal at the last occupancy of the river is put at a greater height above the water-surface than usual, for the purpose of turning the line away from the river as soon as could be done without excessive cutting below the surface. A trial-line on a higher grade was run with an expectation of getting through the point below McKenzie's on the dotted line shown on sheet No. 9. On the line adopted, lock No. 37 could be placed at station 1130, but it would cause deep cutting from station 1150 to 1170, (see profile-sheet No. 6,) which could be avoided by laying the line more to the right at the point of leaving the river; which, however, adds to its length. Two lines were run and leveled around this point, which resulted in the adoption of the present line.

If the dotted line were followed, a deep cut, partly in rock, would be required, while the distance gained over the present line would be only about 1,000 feet.

Further time could not be given to this examination. From McKenzie's Point the line lies over very favorable bottom-lands to station 1215, (see profile-sheet No. 6,) from which point the canal is again formed in the river in the usual manner alongside of the railroad embankment, which is built of the rock excavated from the bluff.

The canal is kept in the river for a distance of 6,000 feet, (nearly one and one-seventh miles,) 1,200 feet of this distance being in an island channel. The proposed widening of the river-channel is shown by the usual shading, (see sheet No. 10.) Thence to Brady's Mills, (station 1292,) a distance of 1,800 feet, the line lies on flat ground. Brady's Mills have long been destroyed, and the dam built for their use has nearly disappeared, the mill-race shown on the map being no longer of any value. It does not require to be crossed by an arch.

ESTIMATE.

This section is estimated to cost as follows:

270.790 cubic yards earth-excavation, at 20 cents	$54,158	00
12,370 cubic yards embankment, (borrowed,) at 30 cents	3,711	00
406,530 cubic yards embankment, at 45 cents	182,938	50
21,900 cubic yards slope-protection, at $2.50	54,750	00
Six locks, 8 feet lift, 1 of 6 and 1 of 7 feet	186,400	00
360 cubic yards culvert-masonry, at $10	3,600	00
Foundations for culvert, on rock	150	00
Seven drainage-sluices and waste-weirs	17,500	00
235 cubic yards abutment-masonry for Winchester Pike, at $10	2,350	00
Foundation for abutment	300	00
Farm-road crossing at Rawlings's	1,500	00
Seven farm-road crossings	9,700	00
Winchester-road crossing	500	00
One hundred and twenty acres land-damages, at $50	6,000	00
Total for 8.16 miles	523,557	50
Average cost per mile	64,109	08

FROM BRADY'S MILLS TO THE TOW-PATH BRIDGE AT THE MOUTH OF WILL'S CREEK, CUMBERLAND, 6.13 MILES.

At Brady's mills the line lies close to a high rock bluff, and cuts deeply into it, in order to reach the bottom-lands just below. (See profile-sheet No. 6.) These bottom-lands extend along the line for a distance of 1 mile, with favorable conditions of cost in construction.

Warrior Run, the largest stream crossed by the canal excepting George's Creek, which was passed at Piedmont, is crossed about one-half mile below Brady's mills. Lock No. 39 is placed below the crossing, for the purpose of passing the creek under the canal by an arch-culvert of 20 feet span. If it should be desirable to feed the canal from this stream, it could readily be accomplished by moving this lock back to near station 1310, forming a pool in the bed of the run, into which it would empty without detriment to the canal.

At a distance of 1⅛ miles below Brady's Mills the canal is again laid in the river for a distance of 1,200 feet, with a tow-path and guard-embankment on the right, the river being widened on the opposite bank, as has been previously done in such cases. Passing out from the river to the left, the canal lies over very favorable bottom-lands for a distance of 2.7 miles. Here it finally enters the river by a guard-lock of 12 feet lift, at the head of the reservoir-pool that feeds the completed canal at Cumberland. This reservoir is used as a basin for the shipment of coal at the wharves of the Maryland Coal Company, being connected with the terminal level of the canal by a lift-lock which is also a guard-lock. The depth of water in the pool at the place where the canal is brought into the river is 7 feet, and it is not less than this at any point along the left bank or elsewhere below the end of the canal.

While the canal practically ends at the head of the reservoir-pool, yet a tow-path must be provided along the left bank of the river to the coal-wharves, a distance of 1.42 miles. The tow-path will be changed from the right to the left side of the canal by a bridge over the tail-bay of the last lock, (No. 34,) which is placed just at the point where the canal enters the river. (See sheet No. 12.) Thence the tow-path must be made by an embankment against the railroad slope for a distance of 1,400 feet. (See section at 1325, profile-sheet No. 7.) The earth for this embankment can be taken from the island at the head of the reservoir-pool by flat-boats, the island being useless for cultivation. There will be no difficulty in making the remainder of the tow-path, as the natural surface is about at high-water line. The bank is covered with a growth of large trees.

A special study will be required to determine the proper way to make the tow-path in front of the wharves so as not to interfere with the business done there. As the condition of our canal will be quite the same as that of the main canal when we have brought it to these wharves, further consideration of the subject may be neglected for the present. Estimate is made for raising the tow-path above high water between the coal-wharves and the tow-path bridge across Will's Creek; and also for protecting the river-bank with stone along the entire distance from the end of the canal to the coal-wharves.

ESTIMATE.

This section is estimated to cost as follows:

220,465 cubic yards earth-excavation, at 20 cents	$44,093 00
11,285 cubic yards rock-excavation, at $1	11,285 00
8,770 cubic yards embankment, (borrowed,) at 30 cents	2,631 00
64,465 cubic yards embankment, (tow-path,) at 60 cents	38,679 00
19,500 cubic yards riprap protection for river slope, at $1.50	29,250 00
Four locks (8 feet lift) and guard-lock	123,750 00
216 cubic yards culvert arch-masonry, at $12.50	2,700 00
286 cubic yards culvert masonry, at $8	2,288 00
150 cubic yards paving culvert, at $3	450 00
Foundation of culvert	150 00
Four drainage sluices and waste-weirs	10,000 00
One county-road crossing	1,800 00
Five farm-road crossings	7,500 00
Tow-path bridge at lock 34	500 00
Clearing river-bank	1,500 00
Eighty acres land-damages, at $50	4,000 00
Total for 6.13 miles	280,576 00
Average cost per mile	45,808 33

RECAPITULATION.

Bloomington to Piedmont	1.84 miles	$418,313 50
Piedmont to station 160	1.10 miles	107,070 00
Station 160 to Keyser	4.17 miles	391,200 00
Keyser to Rawlings's	8.90 miles	623,994 00
Rawlings's to Brady's Mills	8.16 miles	523,557 50
Brady's Mills to Cumberland	6.13 miles	280,576 00
Engineering superintendence, 3 per cent		70,341 33
Total	30.30 miles	2,415,052 33
Contingencies, 10 per cent		241,505 23
Total probable cost of 30.30 miles		2,656,557 56
Average cost per mile		87,675 16

The total length of canal that is laid in the river-bed aggregates 8.05 miles, which is 26.6 per cent. of the whole distance from Cumberland to the mouth of the Savage River.

Table of distances and elevations of various points on the line of the proposed extension of the Chesapeake and Ohio Canal from Cumberland to Pittsburgh, by way of the North Branch of the Potomac and Savage River.

Miles from Cumberland.	Place.	Elevation above low tide.	Remarks.
		Feet.	
0.00	Cumberland, guard-lock of Chesapeake and Ohio Canal.	601.50	Top of miter-sill.
6.18	Brady's Mills	636.00	Surface of water in North Branch.
12.56	Parker's Run	735.40	Do.
23.17	Keyser, (Queen's Rock)	793.50	Do.
28.75	Piedmont, mouth of George's Creek	908.52	Do.
30.68	Bloomington, mouth of Savage	953.29	Do.
35.96	Crabtree Creek, mouth of	1,338.60	Surface of water in Savage River.
44.71	Blue-Lick Creek, mouth of	1,798.60	Do.
54.94	Summit near Shades	2,606.40	
56.55	National Road near Shades	2,418.50	Top of parapet of stone bridge.
61.50	Findlay's Mill, on Piney	2,222.29	Under bridge.
64.62	Piney, mouth of	1,984.80	Near Salisbury.
67.78	Keystone Mines	1,956.60	Surface of water in Castleman.
71.00	Meyersdale, and junction with Will's Creek line.	1,934.40	Castleman at mouth of Flaugherty.

The following maps and plans accompany this report:

Twenty maps Will's Creek route.
Twenty-one profiles Will's Creek route.
Twenty special maps (appendix sheets) Will's Creek route.
Thirteen field-maps North Branch route.
Seven field profiles North Branch route.
Sixteen plans of structures.

I regret that the limited funds at my disposal did not permit me to make as finished maps and profiles of the North Branch route as I could have desired. Those herewith forwarded are the field maps and profiles which, though accurate, are somewhat rough in appearance. The exhaustion of the funds of the survey made it impracticable to have them redrawn.

The plans of structure include seven designs for aqueduct bridges on the Will's Creek route, and also the following, viz:

Design for a lock of 8 feet lift.
Design for a lock of 16 feet lift.
Drawing of lock-gate now in use on Chesapeake and Ohio Canal.
Inclined planes on Morris and Essex Canal; drawings of plane, carriage, flume, turbine and engine-house, and pulley-wheels.
Design for a drainage-gate.
Design for a farm-bridge.

Drawing of canal-boat now in use on the Chesapeake and Ohio Canal.

The appendix attached to this report indicates the manner in which the prices adopted for tunnel and shaft excavation were determined.

Respectfully submitted.

THOS. S. SEDGWICK,
Assistant Engineer.

Major WM. E. MERRILL,
Corps of Engineers.

APPENDIX.

Notes in regard to tunnel-work applicable to the summit-tunnel of the proposed extension of the Chesapeake and Ohio Canal.

In the Nesquehoning tunnel, Carbon County, Pennsylvania, as per paper of J. Dutton Steele, member American Society Civil Engineers, the heading was driven in the conglomerate rock at the rate of 100 linear feet per full month, and in the red shales, 160 feet per month. The work in the conglomerate rock lasted twelve months, and in the red shales two months. The average progress made in widening the tunnel, the heading being in the middle of the bottom of the section, during eight months' working in the coal-measures and two months in the conglomerate, was 166 feet per full month, or 5.53 feet per day, and for the heading 3⅓ feet per day in the conglomerate, and 5⅓ feet per day in the red shale.

The summit-tunnel of the Chesapeake and Ohio Canal extension will be in very similar kind of rock, and the rate of daily progress is not dependent on the area of the tunnel-section, although it may be readily comprehended that the tunnel of larger sections could, with the same proportional number of laborers, be driven somewhat faster than the smaller one, because of the greater air-space and working-room, and the raising of a greater quantity of excavated rock with about the same character and scale of machinery.

The progress in the Hoosac tunnel was 116 and 162 feet per month; and a monthly average for three months of 150 feet, or 5 feet per day.

Presuming that when the rock is solid and forms a self-supporting roof, a greater daily progress can be made than in varying qualities of rock, where the roof must be supported as the work progresses, (requiring a greater number of laborers for the same size of tunnel, and causing many delays,) we will assume that our canal-tunnel can be driven at the rate of 3⅓ feet per day at each face, or 100 feet per month, or 1,200 feet per year. (The average of the daily progress made at the Nesquehoning tunnel is $4\frac{7}{10}$ feet per day.)

The shafts should be larger than is usual, because they would be used so long a time in raising the excavated rock from the tunnel, and for lowering the arching and lining material, &c. They should be arranged with two compartments, one for hoisting and lowering, and one for pumping water and blowing air into the tunnel. This arrangement would require a section for excavation of shaft 10 by 20 feet, giving a quantity of (10′ × 20′ × 700′) 5,185 cubic yards for the shaft of 700 feet depth.

The measure of time for completing the tunnel may be said to depend on the time necessary to complete the western-approach cut, which is 7,100 feet in length, and contains 455,000 cubic yards of earth-excavation and 280,000 cubic yards of rock-excavation. This work being open cutting, a very large force could be kept at work on several lifts or faces at once. It is quite plain that this approach and the 700-foot shaft should be completed in the same time. If two years be allotted to these excavations, we shall have to take 30,625 cubic yards from the approach each month, and from the shaft quite nearly 216 cubic yards per month, or 8⅓ per day, considering twenty-six working days per month. This requires the shaft to be sunk 1⅛ feet per day. Considering the confined space in which the work must be done, and that the laborers must be raised to the top of the tunnel every time a blast in the rock is exploded, this rate of progress is a fair average.

The lining of the shafts with frames of 10 by 10 inch timber, placed 6 feet from center to center, and sheathed with 3-inch plank, would cost, at $50 per thousand feet, $9,890. This sum, divided by the total amount of shaft-excavation, gives an additional cost for lining of $1.91 per cubic yard excavated. No charge is made for lowering the timbers of the lining, as the entire cost of the hoisting-machinery has been taken into account in raising the excavated material of the tunnel.

COST OF EXCAVATING TUNNEL.—WIDENING.

In the Nesquehoning tunnel, the holes drilled per cubic yard in widening were in conglomerate 4½ feet linear measure, and in red shale 3⅙ feet, averaging 3⅓ feet. The quantity of powder used was 3 pounds per cubic yard in the conglomerate rock, and 2½ pounds in the shales, giving an average of 2¾ pounds per cubic yard. One man can drill 8 feet of holes in one day, and one man should break up for loading on to cars, remove from the blasting and load, say, 3 cubic yards per day, and putting labor at $1.50 per day, we have for the cost thus far of one cubic yard of material excavated in widening, as follows, taking round numbers:

Drilling 4 feet of blast-hole	$0	75
2¾ pounds of powder at 16 cents		44
Loading and tamping, say half an hour, 1/20 day		07½
Moving, breaking, and loading, ⅓ day		50
Oil for lights, smithing, and attendance		10
Proportionate cost of foreman: If 3 feet be taken out per day—162 cubic yards—foreman $2.50 per day		01½
Sum of items	1	88
Add 10 per cent. profit		19
	2	07

COST OF HEADING.

The headings in the same tunnel were 8 feet high by 16 feet wide, and were driven at a rate of 100 feet per month in the conglomerate rock, and 160 feet per month in the shale, an average of 130 feet per month. The holes drilled per cubic yard in the conglomerate were 11 feet linear, and in the red shale 6½ feet, an average of 8¾, and the powder averaged 5 pounds per cubic yard. Making an allowance for moving, breaking, and loading of one-half a day's labor for each yard, we have for cost of excavating heading per cubic yard, as follows:

Drilling 9 feet, linear, of holes, 1½ days, at $1.50	$2	25
5 pounds of powder at 16 cents		80
Loading holes, tamping, and lost time ¾ of an hour		11
Moving, breaking, and loading rock ½ day		75
Oil for lights, smithing, &c		15
Proportion of foreman, (1/15,) taking 15 yards from heading per day, $2.50		17
Sum of items	4	23
Add 10 per cent. profit		42
Cost of heading per cubic yard	4	65

TOTAL COST OF EXCAVATION.

The section of our tunnel is 54 cubic yards per each linear foot, and a heading 6 feet high by 12 feet wide gives an area of 2⅔ cubic yards per linear foot, and if three headings were worked at the same time, the sectional area being so large, then the heading area would be 8 cubic yards per linear foot, leaving 46 cubic yards of widening per linear foot, and averaging these portions of the area, we get—

8 cubic yards of heading, at $4.65	$37	20
46 cubic yards of widening, at $2.07	95	22
54 cubic yards of tunnel-excavation, at $2.45⅓	132	42

Averaging $2.45 per cubic yard.

MOVING MATERIAL TO SHAFTS.

Hauling the excavated rock in the tunnel from the working face to the hoisting-shafts will cost as follows, based on the use of a portable tramway and cars carrying one cubic yard, which will weigh, as an average of sandstone, shale, &c., 1½ tons. Taking the average distance of the longest haul in the western section of the tunnel, we shall have 2,100 feet quite nearly. Although we have considered the practicability of driving the faces of the tunnel at a rate of 3½ feet per day, yet, as two full tunnel-faces will deliver their *débris* of material at each shaft, it would require 2 cubic yards to be raised for each five minutes for twenty-four hours—a heavy duty. Presuming for the present that the full tunnel-section will be driven at a rate of 2 feet per day, and allowing an increase in bulk of 50 per cent., there will be 162 cubic yards moved daily from one face. Using a good tramway and allowing one horse to draw two cars, and make a round-trip of 2,600 feet in half an hour, there would be 81 trips per day, or less than one horse could move at 4 yards per hour, and this would require but 4 cars to do the work. We will take, however, 6 cars, and provide 3 horses for 8-hour shifts. We will also consider a double-track tramway as necessary for efficient working, an equipment that would do the work of hauling if the tunnel-face should be driven 3 feet per day. The time for which this equipment will be required will be taken at 5 years, in order to average all the sections of the tunnel, and to renew a portion of the equipment each year, with interest on outlay. We then have—

4,200 linear feet portable track, at 75 cents	$3,150 00
100 linear feet portable track extra at shaft, at 75 cents	75 00
6 cars, at $100	600 00
3 horses or mules, at $150	450 00
3 sets harness, at $20	60 00
Shoeing horses each three weeks, at $1	210 00
Renewal and repairs of track in five years	1,000 00
1 horse each year, 4 at $150	600 00
1 set harness each year, at $20	80 00
Repairs to cars each year, at $100	500 00
Sum of items of capital	6,725 00
Interest at 6 per cent. for 5 years	2,017 50
Value of capital in five years	8,742 50
Value of capital for 1 year of 300 days	1,748 50
Value of capital for 1 day, (300)	5 83

which is the daily expense of capital invested.

The other daily expenses are: three drivers, horse-forage, stabling, and proportion of foreman's wages.

Three drivers, at $1 per day	$3 00
Forage for 3 horses, at 50 cents	1 50
Proportion of stable, hostler, caring for 12 horses, at $1.50	12½
Stabling, cost for 12 horses 5 years, 300 days	12½
Oil for lamps, and lamps, cars, &c	05
One-tenth portion of foreman's wages, at $2.50	25
Daily value of capital invested	5 83
Sum of items of daily cost	10 88

for moving 162 cubic yards of rock, equal to $0.0672, or 6¾ cents per cubic yard.

RAISING THE MATERIAL AT THE SHAFTS.

The wagons used in the tunnel are presumed to be so built as to be run on to a cage or platform at the bottom of the shaft, on which they can be raised to the top of the shaft by the usual arrangements of steam hoisting-engine at any given rate, say 700 feet in one and a half minutes; two platforms to be used, one descending while the other ascends, so as to raise two wagons, 2 cubic yards, each five minutes, one minute being taken at the bottom to load, and one minute at the top to move off the loaded car to be replaced by an empty one. As there are 162 cubic yards to be taken from each of two faces, there are 324 cubic yards to be raised daily. If eight minutes were occupied in raising two cars, 2 cubic yards, the work would consume nearly twenty-two hours, leaving two hours for lowering and raising the laborers to and from their work, the animals to remain always below. Putting the weight of the car at 1,000 pounds, and the platform, on which it is to be raised, at 760 pounds, and 700 feet of steel-wire rope at 1,000 pounds, gives a load of 5,000 pounds to be raised, say 4 feet per second, gives 20,000 foot-pounds—requiring, say, a 40 horse-power engine. The investment of capital in hoisting-machinery and accessories will be as follows, for seven years, to be used two years on the shaft:

Hoisting-engine, complete	$4,500 00
Transportation of same	100 00
1,500 feet steel-wire rope, at 50 cents	750 00
Two platforms, at $75 each	150 00
House for machinery, (arbitrary)	2,500 00
Setting and adjusting machinery	1,000 00
Boilers, complete, (grates, stacks, &c.)	2,500 00
Transportation	75 00
Setting	500 00
Fittings, pipes, &c	300 00
House for boilers	1,250 00
New material and repairs	1,000 00
Sum of items of capital	14,625 00
Yearly value of capital, (300 days)	2,089 30
Annual interest on capital	877 50
Yearly value of capital and interest	2,966 80
Daily value of capital	9 89

The items of daily cost of operating the hoisting-machinery for two shafts are—

2 engine-men, at $2	$4 00
2 firemen, at $1.50	3 00
2 laborers at top of shaft, at $1.50	3 00
2 men at bottom of shaft, at $1.50	3 00
3 horses to take cars at surface, daily value as capitals with renewals	75
Forage of 3 horses and shoeing, at 50 cents	1 50
2 tons coal for fuel, at $4.50	9 00
Oil, waste, and sundries	50
Daily value of capital	9 89
Sum of items of daily expense for raising 324 cubic yards of material	34 64

A cost of 10.7 cents per cubic yard.

Cost per cubic yard of pumping:

1 deep-mine pump	$450 00
1 30 horse-power engine	2,550 00
Transportation	30 00
800 feet 3-inch pipe, at $1.30	1,040 00
30 horse-power boiler	1,100 00
Setting boiler and fixtures	500 00
Pitman for pump, &c	150 00
House for boilers, &c	$1,250 00
New material and repairs in seven years	1,000 00
Sum of items of capital	8,070 00
Yearly value of capital	1,152 87
Annual interest on capital	484 20
Annual value of capital, (300 days)	1,637 07
Daily value of capital	5 46

The daily cost of operating the pumping machinery is as follows:

2 engine-men, at $2	$4 00
2 firemen, at $1.50	3 00
2 tons coal-fuel, at $4.50	9 00
Oil, waste, and sundries	50
Daily value of capital	5 46
Sum of items of daily cost	21 96

Therefore the cost for pumping while 324 cubic yards is being excavated, equals 6.8 cents per cubic yard.

The cost of blowing air into the tunnel is based on the work done by a rotary blower driven by an engine run by steam taken from the boiler of the hoisting machinery:

One pressure-blower	$310 00
5,000 feet blast-pipe, (wood)	1,280 00
Driving-belt	300 00
15 horse-power engine	750 00
Freight	15 00
House for engine	500 00
Renewals and repairs in five years	500 00
Sum of items of capital	3,655 00
Yearly value of capital, (for 5 years)	$731 00
Yearly interest on capital, at 6 per cent	219 30
Yearly value of capital and interest	950 30
Daily value of capital, (300 days)	3 17

(Only the blower, belt, and 800 feet pipe will be used for the first two years in shaft.)

The daily costs are as follows:

2 engine-men, at $2.50	$5 00
2 firemen, at $1.50	3 00
1 ton coal	4 50
Oil, waste, &c	25
Daily value of capital	3 17
Sum of items of daily cost	15 92

Therefore, the cost of blowing air to laborers excavating 324 cubic yards of material is equal to 4.92 cents per cubic yard.

Recapitulating the several items of cost per cubic yard of tunnel-excavation, we have—

Average cost at working-face in tunnel	$2.4500
Cost of hauling in tunnel	0.0675
Cost of hoisting and depositing	0.1070
Cost of pumping	0.0680
Cost of blowing air	0.0492
Sum of items of cost	2.7417
Add 10 per cent. for extra profit	0.2742
Total estimated cost per cubic yard	3.0160

The cost of haul, based on the average distance of haul, is probably somewhat below the actual average, but the same force would do the required work if the length of haul were 2,600 or even 3,000 feet, as the round-trip could be within the half-hour allotted in the above estimate.

A greater quantity of track is allowed than might be found necessary, as there would be no inconvenience in doing the work on a single track with double-track conveniences at the working-face, at the shaft, and at convenient intermediate passing-places as might be needed.

The cost of the machinery and accessories is stated in even figures, for the reason that extreme precision is unimportant; for if a sum of $4,000 capital, with interest, were added to the plant, the cost would be increased only 1.1 cents per cubic yard.

The shoring or false timbering of the work as it progresses is an item of incidental cost more expensive than any of those cited. Providing a complete frame of heavy timber for each linear yard of tunnel, with lagging and props, and the daily labor of three laborers to place it, gives a cost of 55 cents per cubic yard, the material to be lowered in the returning cars. This extra labor, loading return cars, say four laborers, $6 per day, is less than 2 cents per cubic yard. Adding this to former sum of costs, (3.03 + .57,) and adding 11 per cent. for contingencies, gives a cost of ($3,996) say $4 per cubic yard. But if the rock were solid enough to support itself until the linings were in place, $3 would be its cost per cubic yard.

COST OF SHAFTS PER CUBIC YARD.

The area of the shafts is taken 10 feet wide by 20 feet long, to be lined, as sunk, with timber, as previously described.

The cubic contents of the 700-foot shaft is 5,185 cubic yards, or 7.4 cubic yards per each foot of depth, and the shaft must be sunk at the rate of 1½ feet per day, to be completed in two years, requiring a daily removal of 8.63 cubic yards.

The same machinery provided for pumping, raising the material, and blowing air will be needed during the sinking of the shaft, and as its capital value has been distributed to the cost of excavating the tunnel proper, only the daily cost of operating will be taken into the account here.

(A lighter class of plant could be used for working the shaft, but its economy is doubtful, as it would ultimately have to be sold at a sacrifice.)

The cost of operating the machinery may be taken at one-half the laborers and expense required when the machinery is worked up to its full capacity, because the work of sinking the shaft would most probably be done in day-time.

The cost of *blasting and loosening the rock* will be the same as for tunnel-heading.

Drilling holes, 9 feet	$2 25
Powder, 5 pounds	80
Loading holes, tamping, and lost time	11
Breaking and loading rock	75
Oil, smithing, &c	15
Proportion of foreman ⅛	32
Additional lost time, per cubic yard	25
Sum of items	4 63
Add 10 per cent. profit	46
Cost per cubic yard	5 09

The *lining*, according to previous estimates, will cost, for the whole depth, $9,890, or \$1.90$\frac{7}{10}$ per cubic yard. (The daily cost of the hoisting plant being charged to raising the material from the shaft, the expense of lowering the lining-material will not be considered here. It might be taken at one-half the daily expense.)

The *hoisting-expenses* are:

Daily value of capital and interest as before	$9 89
1 engine-man	2 00
1 fireman	1 50
1 laborer at surface	1 50
1 horse drawing cars, top, daily value and cost	1 00
1 ton of coal for fuel	4 50
Oil, waste, &c	10
Sum of items of daily expense	20 49

for raising 8.63 cubic yards, or $2.21¼ per cubic yard.

The cost of *pumping* reduced in the same general manner is:

Daily value of capital and interest as before	$5 46
1 engine-man	2 00
1 fireman	1 50
1 ton of coal for fuel	4 50
Oil, waste, and sundries	30
Sum of items for daily expense	13 76

for 8.63 cubic yards, which is equal to $1.59½ per cubic yard.

Cost of *blowing air:*

(In this case we will presume that the blower is run by the hoisting-engine.)

Daily value of interest, 6 per cent., on $800	$0 16
Blast-pipe, 800 feet, $128	23
Total daily cost	0 39

This corresponds to 8.63 cubic yards of excavation, which is at the rate of 4½ cents per cubic yard.

Summing these items of cost, we have for each cubic yard of shaft removed:

Cost of excavating	$5. 100
Cost of hoisting	2. 215
Cost of pumping	1. 595
Cost of blowing air	0. 045
Cost of lining	1. 907
Sum of items of cost	10. 862
Add 10 per cent. for profit	1. 086
Cost per cubic yard	11. 948
Add 11 per cent. for contingencies	1. 3142
Total probable cost	13. 2622

which may be taken at $13.25 per cubic yard.

R 7.

SURVEY OF MONONGAHELA RIVER FROM MORGANTOWN TO FAIRMONT, WEST VIRGINIA.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, December 11, 1875.

GENERAL: I have the honor to submit the following report on the survey of the "Monongahela River from Morgantown to Fairmont, W. Va.," ordered in the appropriation act for rivers and harbors approved March 3, 1875.

My other duties preventing me from giving personal attention to this survey, I assigned the charge of it to Mr. Thomas P. Roberts, formerly chief assistant engineer on the Ohio River improvement. His report, with accompanying map, (five sheets, including title-sheet,) is herewith forwarded.

The Monongahela River is already slackwatered by permanent dams from Pittsburgh to within a short distance of Greensborough, the total number of dams being 6 and the total length of slackwater 84 miles.

At Hoard's Rock, 94 miles above Pittsburgh, the United States is now building a stone lock and dam which will pond back the river to Morgantown. This lock and dam is number nine of the series, counting up-stream from Pittsburgh, but numbers seven and eight are not yet begun. For full explanations of this anomalous condition of affairs and for detailed information of the river between Morgantown and Greensborough, reference is made to my annual reports since 1872 on the improvement of the Upper Monongahela, which are printed in the annual reports of the Chief of Engineers.

It is the evident wish of the residents along the Upper Monongahela that any improvement of the river should be by permanent dams, as this is the system which has already done good service on the lower part of the river. As a matter of fact, it is not possible to make a perpetual 6-foot navigation without the use of dams of some kind, and the choice is at once limited to permanent or movable dams. The latter are the more costly in construction and in maintenance, and are only justified where there is a comparatively long season of natural navigation, during which dams would be an injury rather than a benefit, or where the mass of moving sand is so great as to make it probable that the pools, if permanent, would rapidily fill up, thus necessitating constant dredging. Neither of these conditions holds on the Upper Monongahela, and therefore I have no hesitation in giving a decided preference to the method of improving by permanent dams.

The difference of level between the surface of the pool now under construction by the Government (which will back water to Morgantown) and the low-water level at Fairmont is 60 feet. This is, therefore, the least sum of the lifts of the necessary dams. The nature of the examination and the high stage of water in the river prevented an exact choice of sites for dams, but the following are Mr. Roberts's approximate locations, which fully agree with my own views in the matter. Retaining the present method of numbering the dams from Pittsburgh, we will then have—

	Feet.
Dam No. 10, at Morgantown, lift	13
Dam No. 11, at Round Bottom, lift	10
Dam No. 12, at Jimmy's Ripple, lift	11
Dam No. 13, at Trippett's Ripple, lift	10
Dam No. 14, at Loweville, lift	10
Dam No. 15, at Holtz's Mill, lift	10
Sum of lifts	64

The reason for giving an extra lift to the dam at Morgantown is fully explained by Mr. Roberts, and it seems a natural consequence of the location. There is a decided advantage in raising the water at Fairmont higher than is strictly necessary, as it extends the upper pool a long distance up the West Fork, thus largely increasing the coal-area that can use this means of transportation.

In the absence of definite locations only approximate estimates can be made. As there are times when there is an undoubted scarcity of water on the Upper Monongahela, I think that the dam should be made of masonry, so as to save all the water possible for navigation. The difference in cost between the two kinds of dams is not great, while in tightness and in durability the stone dam is much the better. The dam now under construction at Hoard's Rocks is of masonry.

I therefore submit the following approximate estimate for stone locks and dams, based on the cost of similar work at Hoard's Rocks:

Six masonry locks and dams, at $130,000	$780,000

As prices have fallen since the contract at Hoard's Rocks was made, it is possible that this sum can be still further reduced. It would also be quite feasible to increase the lifts of the dams, and thus dispense with one of them. This would probably reduce the cost of the system to $650,000, but the locks would be more troublesome to work and require more care in first construction. I would not advise this change except in case of necessity, as experience has shown that lifts of 10 feet are the most advantageous.

Respectfully submitted.

WM. E. MERRILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers.

REPORT OF MR. THOMAS P. ROBERTS, ASSISTANT ENGINEER.

PITTSBURGH, PA., *November* 1, 1875.

SIR: I have the honor to submit the following report upon the survey of the Monongahela River between Morgantown and Fairmont, W. Va., in accordance with your instructions dated June 26, 1875.

Morgantown is the head of the present slackwater improvement now in course of construction by the General Government. Fairmont is 25 miles above Morgantown, and a short distance below the forks of the Monongahela, and is situated upon the Wheeling branch of the Baltimore and Ohio Railroad.

As the Monongahela flows through the richest and most highly developed bituminous coal-fields in the United States, it may be proper in this place to describe its course and the resources of its valley.

GENERAL DESCRIPTION.

The Monongahela is formed a short distance above Fairmont by the junction of the Tygart's Valley River, which heads in Upshur and Randolph Counties in West Virginia, with the West Fork, which heads in Upshur and Lewis Counties.

The Tygart's Valley River is, properly speaking, the parent stream, as it exceeds the West Fork both in volume of water and in length. It drains an area of about 1,390 square miles, and flows in a nearly due north direction, the distance by the meanderings of the river from its head to Fairmont being 135 miles. Its sources interlock with those of the Great Kanawha and the Cheat, and they lie near those of the James River. Through the greater part of its course it is said to be a rough and rugged stream, confined by hills and mountains. Its water-supply is well maintained by perennial springs. Beverly, Philippi, and Grafton are the only important towns in its valley. Generally speaking, the Tygart's Valley is a valuable mineral and timber region, but the known excessive fall in the river precludes the hope that it will soon be developed by an extension of the Monongahela slackwater. Much has been already accomplished, however, by the Baltimore and Ohio Railroad in settling this region and in making known its resources.

The West Fork River is not quite so long as the Tygart's Valley branch, and has quite different characteristics. Its general course is northeast, which direction is maintained by the Monongahela to Morgantown. Unlike the Tygart's Valley River, its flow is comparatively sluggish, and it is generally believed to have less fall per mile, at least for the 35 miles from its mouth to Clarksburgh, (where it is crossed by the Parkersburgh branch of the Baltimore and Ohio Railroad,) then the Monongahela itself above the Pennsylvania line.

About forty years ago a Mr. Jackson obtained from the settlers and lumbermen of those days $30,000, which he expended in the improvement of the West Fork, and actually constructed ten or eleven dams, with an average lift of about 4 feet. The dams were built without locks, and exactly what was expected from them has never been clearly understood; possibly it was intended to place chutes in them for the passage of rafts. They were built of logs, in a very imperfect manner, and for want of care soon fell into decay. In those days the value of the coal deposit in this extraordinary region was entirely unknown, and, indeed, even yet it can be said to be illy appreciated even by those who claim to understand the mineral resources of the State of West Virginia.

The West Fork is said to maintain its favorable feature of slight fall not only to Clarksburgh but to Weston, some 40 miles farther up. If this be so, there is a total distance of 75 miles above the head of the Monongahela, and in the heart of the coal-field, where an improvement by slackwater or by canal would have but few locks, and would therefore be comparatively free from the loss of time and the annoyance incident to excessive lockage. The West Fork has, during several months of the year, a very limited supply of water, probably caused by the fact that its tributaries flow through fertile agricultural regions on which there is a large amount of surface-evaporation. It is to be presumed, however, that a regular water-supply could easily be arranged by cheaply-constructed reservoirs, should an improvement of the river necessitate them. The area of the West Fork Valley is about 910 square miles.

I dwell more particularly on the mineral resources and susceptibility for easy improvement of the West Fork because I believe on general principles that an improvement by slackwater or canal will certainly ultimately be made where the natural conditions are so promising. It will first be necessary, however, to secure the slackwater to Fairmont, and, as this is yet in the future, we may content ourselves for the present with a general indication of the advantages of a subsequent extension up the West Fork, without discussing its details.

Below the forks the Monongahela maintains a general northeast course to Morgantown, 27 miles. As is shown in the profiles accompanying this report, the fall in this distance is only 55 feet, which is an average of about 2 feet per mile. It will be observed also that much the greater portion of the fall occurs in the lower half of this distance. Each of the two upper dams proposed in this report has a lift of 10 feet, and ponds back the river for a distance of 9 miles. In fact, the fall near the upper end of the Monongahela is but little greater than it is near its mouth at Pittsburgh. This flat place on the river is a marked and very important feature.

From Morgantown the general course of the river is due north, 102 miles to Pittsburgh, and in this distance it falls 93 feet.

THE MONONGAHELA COAL.

Before the completion of the present slackwater navigation in 1842 some coal was brought down the Monongahela in flat-boats, even from as far up as Fairmont, but, owing to the limited demand for fuel in the West and South, the trade was insignificant. But of late years the demand for this superior coal in the southern and western cities, where it is chiefly consumed, has become so great that the coal-trade has become the leading business, not only on the Monongahela but also on the Ohio. All of the so-called "Pittsburgh" coal is the product of the valleys of the Monongahela and its lowest tributary, the Youghiogheny. I append herewith a statement of the coal-shipments through the Monongahela Navigation Company's locks since November, 1844, with a statement of the annual receipts of tolls, which clearly exhibits the surprising growth of this trade:

Year.	Shipment of coal, in bushels.	Tolls.	Year.	Shipment of coal, in bushels.	Tolls.
1844	737, 150	....	1860	37, 947, 732	$52, 028 07
1845	4, 605, 185	$3, 383 79	1861	20, 865, 722	30, 945 92
1846	7, 778, 911	10, 221 28	1862	18, 583, 956	26, 7[illegible] 29
1847	9, 645, 127	13, 241 94	1863	26, 454, 252	40, 552 08
1848	9, 819, 361	12, 438 43	1864	35, 070, 917	61, 384 29
1849	9, 708, 507	13, 533 30	1865	39, 522, 792	69, 608 48
1850	12, 297, 967	17, 023 57	1866	42, 615, 300	77, 811 26
1851	12, 521, 228	17, 850 24	1867	30, 072, 700	54, 855 63
1852	14, 630, 841	20, 014 18	1868	38, 301, 000	91, 376 39
1853	15, 716, 367	21, 291 86	1869	52, 512, 600	104, 936 61
1854	17, 331, 946	25, 079 51	1870	57, 596, 400	118, 705 68
1855	22, 234, 009	31, 050 58	1871	48, 621, 300	100, 338 64
1856	8, 584, 035	10, 566 42	1872	54, 208, 806	115, 609 90
1857	28, 973, 596	37, 111 41	1873	56, 173, 238	116, 728 75
1858	25, 696, 069	34, 353 49	1874	65, 881, 700	137, 489 58
1859	28, 286, 671	39, 065 65			

Besides coal, there are annually shipped through the locks about 3,000,000 bushels of coke. There are employed in the coal-traffic about 125 tow-boats and about 3,000 barges and coal-boats, the latter varying in capacity from 400 to 700 tons each. The coal from the different pools sells for different prices in the southern and western markets. I have learned upon inquiry that coal from the first and second pools above Pittsburgh sells for from 1 to 2 cents a bushel more than that from the third and fourth pools. It is stated by some that the coal from the upper pools is not so good for gas purposes, and that barges loaded with the upper coal are always rejected from the fleets when coal from the lower pools is plenty. The market quotations in the papers occasionally show that the coal from pools three and four will sell for no more than Kanawha coal.

I would beg to call your attention to these statements; they will have a bearing upon the question whether coal when brought to market from points still higher up the Monongahela, and not yet reached by slackwater, will be able to compete with coal mined in the pools of the existing slackwater.

The tolls at present exacted at the locks are 1 mill per bushel from the first pool, 2 mills from the second pool, 2¾ mills from third pool, and $2\frac{95}{100}$ mills from the fourth pool. It is understood that this arrangement is made for the purpose of encouraging mining operations on the upper pools. It will be observed, however, that besides the difference in market-value, which is against coal from the upper pools, it must also stand a greater taxation for lockage and towing.

It costs now about 3 cents per bushel to mine coal in the first, second, and third pools, and from 2½ to 2¾ cents in the fourth pool.

The value of coal-land is quite different in the several pools, varying as much as from $900 per acre in the first pool to $150 in the fourth pool. (Little or no mining is at present attempted in the fifth and sixth pools.) In order to more readily exhibit these features of the coal-business on the Monongahela, I append the following tabulated statement:

Pools.	Value of coal-property per acre.	Lockage to Pittsburgh, per bushel.	Towing to Pittsburgh, per bushel.	Towing and lockage, per bushel.	Cost of mining in 1875, per bushel.	Bushels mined in 1874.
	Dollars.	*Mills.*	*Mills.*	*Cents.*	*Cents.*	
1	900	1	1½	¼	3	9,113,500
2	600	2	3	½	3	33,516,700
3	250	2¾	4½	¾	3	11,440,800
4	150	2.95	7.05	1	2½	11,810,700

The coal-vein worked is generally about 4½ feet thick, and the product is about 100,000 bushels per acre. The lockage, therefore, amounts to a tax of about $100 per acre for the first pool, $200 for the second, $275 for the third, and $295 for the fourth pool. The cost of towing more than doubles this tax.

THE UPPER RIVER COAL.

At the termination of our survey, when my party reached the enterprising town of Fairmont, I was called upon by a committee of citizens interested in the improvement of the river. * * * In company with committees of citizens I visited the most important works of the neighborhood; among others, the West Fairmont Coal Works, owned by a New York Company and managed by Mr. C. M. Davidson. These works are situated on Buffalo Creek, on the line of the Baltimore and Ohio Railroad, about a mile west of the town; the company mine on both sides of the creek, crossing it by an inclined plane 1,000 feet long, which descends into the mine on the opposite side. The vein is between 9 and 10 feet thick, and has a slope of about 3 feet in 100, dipping northwest, which is the general inclination of the entire geological series of the country for many miles both above and below Fairmont. The river, running at right angles to the dip, or northeast, is therefore most favorably disposed in a course parallel with the outcrop. Besides the heavy vein, there are others both above and below it, some hills having a workable thickness of over twenty feet of good coal. From the West Fairmont Coal Works 300 tons are daily shipped by railroad to New York and elsewhere. Their chutes, tracks, and buildings are equal to any I have ever seen. Attached to the works are 50 coke-ovens, this coal being said to be admirably adapted for coking. The total amount invested in the mines is $85,000. In company with Messrs J. J. Burns and A. B. Flemming I also visited the Gaston mine, situated on the West Fork River, 1 mile above its mouth. It is connected with the Baltimore and Ohio Railroad by a well-built branch road constructed by the coal company, on which they have a light engine. The full capacity of their works is about 500 tons per day, and they have been developed to about 250 tons per diem. The vein is 10 feet thick. When I visited this place I saw some coal on cars which was destined for Detroit, Mich. The Fairmont coal is essentially a gas-coal, and is held in high repute in New York, Boston, Baltimore, Washington, and other places both East and West, to which it is shipped. One firm shipped in a single season to the New York and Brooklyn gas companies as much as 30,000 tons, or 840,000 bushels. It is affirmed by some that this coal exceeds in gas-production per pound that from the celebrated Penn or Westmoreland coal-field on the Pennsylvania Railroad, but that it requires somewhat more lime and a greater proportionate capacity in the purifiers. I could obtain no tables of analyses by which to compare them, but the fact at once impressed itself on my mind that this coal must be a very superior article to be able to pay the rate to eastern markets demanded by the Baltimore and Ohio Railroad. The Fairmont people, rather unjustifiably I think, blame that company for excessive rates. Their coal is sold in New York, distant 474 miles, for $6.50 per ton. When the heavy grades of the Baltimore and Ohio Railroad over Laurel Hill and the main Alleghany range (116 feet per mile for many consecutive miles) are taken into consideration, together with the distance, it is a wonder there should be any trade at all from this region. I was informed that 2,000,000 bushels, or about 70,000 tons, are annually shipped from Fairmont. The same coal is also shipped in large quantities from Clarksburgh, 35 miles up the West Fork, via the Parkersburgh branch of the Baltimore and Ohio Railroad. But so long as other gas-coal fields nearer the market can furnish a supply, I think the trade of this region, as now done by railroads, must necessarily be cramped, and that it will not expand materially. But it strikes me that, no matter what may be the rates of toll established on any slackwater improvement reaching the Fairmont coal-fields from the Ohio, it would at once afford a better outlet. The fact that this place has already demonstrated its possession of a good article in universal demand, which cannot at present be brought into general use on account of the cost of transportation by rail, is an excellent argument in favor of cheap transportation by water. The question now coming up is whether, in the event of slackwater to Fairmont, this coal will compare favorably in quality and price with that found on the river below, which already enjoys not only a reputation for good quality, but the cheapest rates of transportation known in the United States. If it should appear that this coal is not so good as that in the pools below, it would suffer in the markets in comparison, and the additional tax for lockage would add materially to the difference against it. Basing an opinion on the large shipments made by rail to distant points from this region, I am tempted to believe this upper-river coal equal in all respects to the best found near Pittsburgh; but it might be as good, and still not valuable enough to pay the difference in river-transportation rates.

The main point claimed for it in comparison with Pittsburgh coal is that the vein is more than twice as thick, and is, consequently, much more easily worked. Near Pittsburgh the average daily production per hand is 100 bushels, for which 3 cents per bushel is paid. The average daily production per hand in the Fairmont mines is 300 bushels, for which 1¼ cents per bushel are paid. (Some miners are paid only 1 cent a bushel.) This is a difference in cost of mining in favor of the upper-river coal of 1¾ cents per bushel, and, at the same time, better wages are made by the miners. Coal-properties are held along the Baltimore and Ohio Railroad, according to location, at from $75 to $150 per acre; some has been sold as high as $300 per acre. It should be borne in mind that the railroad traverses the coal-field at right angles to the strike, and passes entirely through the belt of the heavy vein in a distance of less than 5 miles, whereas the Monongahela meanders through it parallel to the strike for over 25 miles, not including the distance to Clarksburgh, which is a part of the same coal-field, and is traversed by the West Fork. Purchases of coal-privileges could doubtless be made along the river for from $10 to $25 per acre. Putting it at $50 per acre, it has already been stated that coal-privileges near Pittsburgh, in the lower pool of the Monongahela, are valued at $900 per acre; this shows the advantage of the Fairmont region in cost of land. From Fairmont to Pittsburgh there would probably be fourteen locks to be passed through, or fifteen if the slackwater should be extended so as to embrace one pool up the West Fork River, as I would recommend. Seven of these locks would be owned by a corporation and the other seven or eight controlled by the United States Government, should the latter build this improvement. If the charges for lockage should diminish as the pools are more distant from Pittsburgh, according to the system already introduced by the Monongahela Navigation Company, the entire amount of tolls would not probably exceed 8 mills per bushel from Fairmont to Pittsburgh, and might be made even less, most of the upper pools being short, and, for other reasons, some reduction could be relied upon for through-rates of towing. I have been informed by river-men that towing could be done for about one cent and eight mills per bushel.* This would make the cost of coal at Pittsburgh about 8¼ mills per bushel more than Pittsburgh coal. This difference is precisely made up by the money saved on the land-purchase at the assumed figures. But aside from this, the Fairmont coal can safely be presumed to enter and leave pool No. 4 on a par with coal from that pool, if its quality is superior, as I assume it to be. The General Government having already embarked in the improvement of this river and provided for the construction of one dam, backing the water to Morgantown, within 8 or 10 miles of the Fairmont coal-field, and almost within sound of trains passing over the Baltimore and Ohio Railroad, has fairly placed itself in a position from which it cannot recede until the real object has been attained for which the extension of the slackwater is urged, viz, the opening up of the resources of the State of West Virginia and the completion of a line of communication that shall have an outlet for general commerce *at both ends.* As it is, the slackwater falls short of reaching the best coal-fields, and terminates where it may never expect to benefit general commerce by furnishing cheaper transportation than railroads can afford. The great city of Pittsburgh is vitally interested in this region. Within a radius of 100 miles of her there are embraced within the limits of West Virginia 4,750 square miles, 2,630 square miles of which are on the Monongahela River, which flows past her work-shops, but is now tributary to a railroad that does not lead toward Pittsburgh. This region includes the well-settled and populous counties of Marion and Monongalia, and also Harrison, Tucker, Taylor, Preston, and Barbour, with parts of Randolph and Upshur.

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* This figure bears no comparison in point of cheapness to the towing-rates on the Ohio River from Pittsburgh. The barges are brought down the Monongahela either

MINOR INTERESTS.

Among the minor resources and industries of the Upper Monongahela to be benefited by a river improvement is the lumber-trade. The slopes of the hills and mountains of this part of West Virginia were at one time covered with magnificent forests of oak, black walnut, locust, hickory, linden, and other woods, and an extensive trade in rafting lumber was carried on to supply the demand for steamboat and barge construction and for general building purposes. The oak from this region bears in Pittsburgh the best reputation of any that comes to that market. But within 5 or 6 miles of the river and its principal tributaries the forests have been generally cleared. As far as my survey extended the country presents a beautiful, high, rolling landscape, and it is as well cleared as the adjacent counties of Pennsylvania. However, toward the Cheat Mountains and above, on the headwaters, extensive forests are standing that as yet have been scarcely culled. The soil on the hills is remarkable, from the fact that it is as well adapted for grain and corn as that along the river-bottoms. The extent of bottom-land along the Monongahela is everywhere limited, and it is extremely fortunate for agriculturists that the soil on the hills—and it is all hilly—should be so good. In respect to soil and climate, this part of West Virginia is superior to the average of Western Pennsylvania. The country adjacent to the river is settled by a thrifty and intelligent people, possessing comfortable homes. About 200 rafts of oak and poplar are floated down annually in freshets, principally from the West Fork River. There is besides a considerable quantity of sawed lumber, staves, shingles, hoop-poles, and cross-ties shipped by river from this region. Some lime and fire-brick are sent down in flat-boats from near Fairmont, the aggregate value of which I was unable to obtain. Fruit-culture promises in the near future to be an extensive item in shipment. In the neighborhood of Newport, 8 miles below Fairmont, in two orchards alone there are 10,000 bearing apple-trees. Iron-ore in great quantities is found along the Cheat River and at many points also along the Monongahela. Three furnaces have recently been in blast in the Tygart's Valley, but as to the character of the ores used I was unable to learn anything. Some distance above Morgantown, near the Little Falls, I examined the outcrops of a vein of ore on the river-bank that I judge would yield 25 to 30 per cent. It is rich with lime, and, it is said, has been used without a flux in the Old Clinton Furnace, formerly standing near the spot. I apprehend, however, that this ore could not be profitably used by itself, but as it possesses so much lime it might possibly be introduced in Pittsburgh, to be used as a flux and for mixing with the richer ores from the Lakes and from Missouri. At many points along the river I observed ledges of very superior sandstone, very suitable for ornamental-building purposes. The building-stone of this region is certainly more durable and it presents a better texture and appearance than most of that employed in Pittsburgh. The latter city is badly situated for building-material, the nearest quarries of fair stone being over 20 miles distant by rail, and much that is used comes from points on the Pittsburgh, Fort Wayne and Chicago Railroad, more than 100 miles distant; so that the quarries along the Monongahela above Morgantown would possess a new value should the slackwater be extended to them. Near Fairmont there are very extensive deposits of glass-sand, an article in greater demand in Pittsburgh than in all the cities of the Union combined. I was informed that this

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singly or in pairs, and are made up in large fleets of ten or more at Pittsburgh, and then taken in tow by large and much more powerful tow-boats. Calculation of cost of towing on the Ohio will generally show that it is no more than 1 mill per ton per mile to Cincinnati, and less in proportion as the distance is greater, as to Louisville, Memphis, or New Orleans. In this is included the cost of returning the empty barges to Pittsburgh.

sand is shipped to the Wheeling Glass Works by railroad, but none of it, I believe, has so far reached the Pittsburgh works. Deposits of potter's-clay are also found in the same neighborhood, and recently an extensive pottery-establishment has been erected in Palatine, immediately opposite Fairmont. The two towns are connected by quite a handsome suspension-bridge, 550 feet long. There are a number of pottery-establishments on the Monongahela, near Greensborough, the head of the completed slackwater improvement, the shipments from which by river are quite large.

It should not be lost sight of, in conclusion, that by the extension of the slackwater to the Baltimore and Ohio Railroad, a considerable passenger, express, and general freight business would be benefited, the facilities for which are at present only a wagon-road and stage-line; sometimes two coaches leave for Rivesville and Morgantown daily from Fairmont. There is certainly a more promising expectation for light business along the Monongahela Valley than has been vouchsafed many railroad-enterprises at the start. It is proper to add that a line of railroad has already been located on the river-bank, which is to extend from Pittsburgh, via Fairmont and Clarksburgh, to Charleston, W. Va., and that 35 miles of this road has been built from Pittsburgh south and is now in running order.

THE DAMS, WATER-SUPPLY, ETC.

I have indicated on the profile the situations and lifts of the several dams that would appear to me, from the observations I made in the limited time of making the survey, as suitable for the extension of the slackwater. Unfortunately, during nearly the entire time I was engaged on the survey the river was swollen and muddy, from the effects of the remarkable rains that visited the Central States in July and August, so that I was prevented from making as careful an examination for dam-sites as would be required in case actual locations had been ordered. I feel confident, however, that, as a rule, this portion of the Monongahela River will be found to have generally a good rock bottom. At some places rock ledges cross the river horizontally from bank to bank. At other places where such favorable disposition may not be found for foundations, a comparatively shallow excavation would be required on only one side in order to reach the rock bed of the river. There are exceptional places near the mouths of the largest creeks where large masses of loose rock have been carried into the river as though they had been pushed along by glacial action. At such places, to reach the solid rock, a greater depth of excavations would be required, but I think it will be found that at the points designated for dams the bottoms are uniform. The most unfavorable site is at Lowe's Mills, but this may prove not as bad as anticipated, as I could not judge very well of its character on account of the depth of the water. The dams are numbered from Pittsburgh up. At Morgantown the tenth dam will possibly be erected. I would propose that its lift be made 13 feet, in order that it may pond the water above Booth's Creek, in order to avoid placing a dam at this place, as would be necessary if a much lower lift were adopted. At Booth's Creek the river is wide, and it appears to be greatly filled up with loose rock. With a lift of 13 feet the pool of dam No. 10 will have more than twice the length it would have if the lift were made only 10 feet, as there is a long natural pool just above Booth's Creek which will become a part of it. For dam No. 11, I would propose a location at the lower end of Round Bottom. At that point the foundation is good. I would recommend that the lift be made 10 feet. Dam No. 12 would be just above the present fish-dam in Jimmy's Ripple. At this place both banks and the bottom of the river appear to be solid rock. This dam might be made 11 feet lift, in order to back the water over the Little Falls. There is a sharp bend in the river at the Little Falls, and I think it would be better to locate the dams as remote as possible from such points. Dam No. 13 would be about midway up in Trippett's Ripple. The foundations at this place appear to be good; the lift is 10 feet. Dam No. 14 would be at Lowe's Mills. At this point there is a valuable mill-property, and quite a settlement. I think it would be well, if possible, to arrange a dam at this point, not only on account of the accommodation the locks would be for passengers, but also to afford power to any mill that might be arranged to use the waste-water. I would recommend that at this point one or more iron pipes be laid in the abutment, with proper valve-connections that would afford power when there was water to spare.

Dam No. 15 would be at Holtz's Mill; it would have 10 feet lift. I regard this as a very favorable location. An arrangement for the accommodation of mills might be made at this point also. In proposing this arrangement of dams, I am aware that I have exceeded the lift merely necessary to extend the slackwater to Fairmont, but I believe it a great desideratum to have the water backed up the West Fork River, as thereby several thousand acres of the "11-foot" coal-veins would be made accessible. Including this last dam, there would, therefore, be required six dams, as I have proposed to arrange them. Omitting this last dam and giving to all the others a higher average lift, four dams in all might answer. I am not prepared to say whether there would be any practical economy in resorting to higher lifts. There may with higher lifts be more of a question about endangering the banks. I think, undoubtedly, at many points, unless the banks are protected by willows, that they will cut in any event. Farmers complain now that the floods are more destructive than formerly to the banks, but, on the whole, I think not much damage, reckoned in money, either by overflow or cutting, would ensue by making the dams higher, as the bottom-lands are usually very contracted and possess no particular value. But by this cutting the water-surface would be enlarged, and the loss by evaporation would accordingly be proportionally greater. I have entered into no calculation of the cost of dams of given heights, but think, for economy in time of working and safety, a lift not materially over 10 feet is best. I believe that this lift has come to be considered the standard for slackwater on small streams and canals. As far as I could learn, the ice does not promise to give much trouble on the Upper Monongahela. In this respect the river is better than it is lower down, where the difference in latitude is marked by more severe freezing weather. Gorges seldom occur, and have never been known to do any serious damage or to cause overflows. I regret that I was unable to carry out your instructions in respect to gauging the river, for it appears there are no records obtainable of the low-water discharge of the Monongahela above Cheat River. The lowest water while we were making the survey was at the start, early in July, when it was about 9 inches above low-water mark. After that the river fluctuated between a flood-stage and 2 feet above low-water mark. The flood on the Monongahela was more marked at its headwaters than it was farther north. The greatest rain-fall appeared to culminate in the West Fork River Valley; and toward the last of this remarkably rainy season the greatest downfall was on Buffalo Creek, where a flood occurred entirely unprecedented for height. At Mannington, on this creek, and also on the Baltimore and Ohio Railroad 17 miles west of Fairmont, a road-bridge was swept away, and many thousands of dollars' damage was done, the water having stood 4½ feet deep in the stores of the business part of the village. At Fairmont, and at Morgantown also, the extreme rise was 25 feet above low-water mark, but no damage was done, excepting by the loss of rafts and boats. The highest water known at Fairmont was in 1832, when the river rose 34 feet above low-water mark. I roughly estimated that for one week (July 28 to August 4) the average depth of the river at Fairmont was 15 feet, with a current of 6½ miles an hour, passing 4,000,000 cubic feet of water per minute.

In seasons of drought the creeks between Morgantown and Fairmont are practically dry, and the sole reliance for water must be placed on the Tygart's Valley River and the West Fork. It is believed by many that the river at such periods has more water at Fairmont than it has at Morgantown. I have no means of knowing, even approximately, the low-water discharge, but there is said to be always an ample supply for both the grist-mills at Fairmont, with water to spare. The most intelligent mill-men, and others with whom I conversed, thought there would always be an ample supply for slackwater purposes. I think myself, as there need be no rush of business at any time at the locks, the dams will remain full, and that a 6-foot navigable depth can be maintained in the Upper Monongahela at all times, save when the river may be closed by ice. The following table shows the distances from Pittsburgh of various points on the Upper Monongahela, the lengths and falls of the ripples and dams, and the elevations of low water above low water at Pittsburgh, and above the mean ocean-level:

Distance from Pittsburgh.	Place.	Elevation of low water above low water at Pittsburgh.	Elevation of low water above mean ocean-level.	Rise of ripple.	Length of ripple.	Remarks.
Miles.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	
0	Pittsburgh	0	699. 16	......	....	
102. 25	Morgantown Bridge	89. 97	789. 13	......	....	
103. 72	Cobun's Run	91. 35	790. 51	......	....	Began survey July 3, 1875.
105. 30	Morgan's mill-dam, below	94. 47	793. 63	......	....	In this distance the river is wide and filled up with loose rock.
	Morgan's mill-dam, above	98. 37	797. 53	3. 90	....	
106. 62	Booth's Creek Ripple, foot	98. 82	797. 98	......	....	
	Booth's Creek Ripple, head	99. 51	798. 67	0. 69	77	
·107. 76	Round Bottom Ripple, foot	101. 21	800. 37	......	....	
107. 96	Round Bottom Ripple, head	102. 31	801. 47	1. 10	1, 082	Solid rock bottom.
108. 93	Gray's Rapid, foot	102. 94	802. 10	......	....	
108. 96	Gray's Rapid, head	103. 87	803. 03	0. 93	190	Rock-ledge across bottom.
109. 12	Frum's Ripple, foot	104. 20	803. 36	......	....	
109. 66	Frum's Ripple, head	106. 98	806. 14	2. 78	2, 350	Series of short ripples.
110. 05	Jimmy's Ripple, foot	107. 14	806. 30	......	....	
110. 71	Jimmy's Ripple, head	114. 61	813. 77	7. 47	3, 390	Do.
111. 16	Little Falls, foot	115. 37	814. 53	......	....	
111. 26	Little Falls, head	117. 16	816. 35	1. 82	400	Solid rock bottom.
111. 73	Joe's Run Ripple, foot	117. 94	817. 10	......	....	
111. 90	Joe's Run Ripple, head	119. 01	818. 17	1. 07	920	Old fish-dam.
112. 34	Trippett's Ripple, foot	119. 30	818. 46	....	....	
112. 77	Trippett's Ripple, head	122. 49	821. 65	3. 19	2, 299	Fish-dam in ripple.
113. 10	Sapp's Ripple, foot	122. 51	821. 67	......	....	
113. 36	Sapp's Ripple, head	123. 51	822. 67	1. 00	1, 400	
114. 40	Big Falls, foot	124. 68	823. 84	......	....	
114. 60	Big Falls, head	127. 56	826. 72	2. 88	1, 050	Solid rock-ledge.
115. 46	Lowe's Ripple, foot	127. 81	826. 97	......	....	
	Lowe's Ripp'e, head	129. 87	829. 03	2. 06	200	Ruins of old dam and mill.
116. 51	Loweville mill-dam, below	131. 62	830. 78	......	....	
	Loweville mill-dam, above	134. 92	834. 08	3. 30	....	Hood & Wisman's mill.
121. 37	Laban's Ripple, foot	137. 20	836. 36	......	....	
121. 48	Laban's Ripple, head	137. 95	837. 11	0. 75	615	Gentle ripple.
122. 17	Hayman's Ripple, foot	138. 03	837. 19	......	....	
122. 37	Hayman's Ripple, head	139. 54	838. 70	1. 51	2, 069	Loose rock bottom.
125. 42	Holtz's mill-dam, below	141. 72	840. 88	......	....	
	Holtz's mill-dam, above	144. 57	843. 73	2. 85	... .	Solid rock bottom.
125. 77	Head of ripple above dam	146. 64	845. 80	4. 92	1, 800	
128. 07	Fairmont Dam, below	147. 26	846. 42	......	....	
	Fairmont Dam, above	149. 21	848. 37	1. 95	....	Two mills.
129. 67	The Forks	149. 94	849. 10	......	....	Junction of the Tygart Valley River and the West Fork.

Respectfully submitted.

THOMAS P. ROBERTS,
Assistant Engineer.

Maj. WM. E. MERRILL,
Corps of Engineers.

APPENDIX.

The following printed statement has been forwarded to me from Fairmont, from which it appears that at a recent test made at the Chicago water-works, Fairmont coal pumped 528 gallons of water per pound of coal consumed. Of the coals named in the table, the Briar Hill comes from the line of the Pennsylvania Railroad, and the Ft. Pitt, Walnut Hill, and Cherry Mines, from the line of the Pan-Handle Railroad. The Lackawanna is from the Eastern Pennsylvania, and, as far as I know, is the only anthracite coal on the list.

Official test of coal at Chicago water-works.

Number.	Date.	Kind.	From whom.	Hours run.		Quantity.		Revolutions.	Total gallons water pumped.	Gallons of water per pound of coal.	Comparative value per cent.
	1870.			*hs.*	*m.*	*Tons.*	*lbs.*				
1	May 3 to 5	Trippett	Rhodes & Bradley	71	45	51	360	55, 563	37, 110, 743	362. 5	100. 0
2	Apr. 25 to 28	Willow Bank	Waldron	71	10	75		83, 975	56, 241, 232	374. 9	103. 4
3	Apr. 22 to 23	Briar Hill	Rhodes & Bradley	50	40	52	272	60, 876	40, 592, 071	389. 2	107. 3
4	....	Glenco	Dutton	35	05	47	420	49, 376	38, 896, 790	412. 0	103. 6
5	May 5 to 7	Pearl	J. W. Walker & Co	52	55	51	1, 250	63, 748	42, 581 673	412. 4	113. 7
6	Apr. 23 to 25	Ft. Pitt	Rend	54	30	51	1, 860	63, 952	42, 957, 960	413. 6	114. 0
7	Apr. 18 to 21	Pittsburgh	McCauley	54	50	51	140	63, 907	42, 559, 962	416. 6	114. 9
8	Apr. 28 to 30	Walnut Hill	Ames	56	50	53	1, 510	67, 353	45, 107, 868	419. 5	115. 7
9	Oct. 18 to 19	Lackawanna	....	48	00	49	1, 150	49, 416	42, 208, 364	425. 6	117. 4
10	Sept. 9 to 20	Hocking Valley	Ames	288	00	352	260	347, 667	300, 416, 866	426. 5	117. 6
11	May 1 to 3	Cherry Mines	Taylor	60	25	54	1, 570	69, 706	46, 800, 855	427. 0	117. 7
12	Sept. 1 to 9	Hocking Valley	Rend	192	00	235	1, 900	240, 083	206, 293, 815	437. 1	120. 5
13	Sept. 21 to 22	Fairmont	....	42	30	44	1, 470	56, 658	47, 251, 650	528. 1	145. 7

The following, being an ordinary weekly statement published in the Engineering and Mining Journal of New York, (taken from the issue of October 9, 1875,) is presented to show that Fairmont coal in the eastern gas-coal market stands "alongside" on equal terms with any other plain bituminous gas-coal from American mines. It should be borne in mind that the various cannel-coals quoted are chiefly valuable for mixing with coals weak in gas. Cannel-coal is entirely too fat to be used alone in large gas-works as at present constructed, and is equally unsatisfactory for this reason when used for steam-purposes, and therefore comparatively small quantities of it are employed. All of the regular gas-coals quoted in the table are nearer market than the Fairmont coal; if we prorate for grades, the distance to New York becomes even more favorable for the coal from other regions. It must be chiefly because the coal is of a superior quality, and is cheap to mine, that it enters the market at all.

Wholesale prices of bitumiuous coal—domestic gas-coals—per ton of 2,240 pounds.

Variety.	At the shipping ports.	Alongside in New York.
Westmoreland and Pennsylvania, at Greenwich, Philadelphia	$5 20	$6 50
Westmoreland and Pennsylvania, at South Amboy	6 00	6 50
Red Bank cannel, Pennsylvania, at Philadelphia	8 00	8 50
Red Bank cannel, Pennsylvania, at South Amboy	9 50	....
Red Orrel	6 00	6 50
Youghiogheny, Waverly, county of Baltimore	5 00	6 50
Despard, West Virginia	5 00	6 50
Murphy Run, West Virginia, at Baltimore	4 75	6 50
Fairmont, West Virginia, at Baltimore	4 75	6 50
Newburgh Orrel, Maryland, at Baltimore	4 75	6 50
Cannelton cannel, West Virginia, at Richmond	9 50	11 00
Cannelton splint, West Virginia, at Richmond	5 00	6 50
Peytona cannel, West Virginia, at Richmond	9 50	11 50
Straitsville cannel, at Sandusky, Ohio	3 25	10 00

R 8.

EXAMINATION OF THE LOUISA FORK OF SANDY RIVER, FROM THE MOUTH OF DISMAL, IN BUCHANAN COUNTY, VIRGINIA, TO PIKETON, KENTUCKY.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, January 6, 1876.

GENERAL: I have the honor to forward herewith the report of Mr. James E. Bell, assistant engineer, on the examination of the Louisa Fork of the Big Sandy River, between Piketon, Ky., and the mouth of Dismal, in Virginia. The examination was ordered in the appropriation bill for rivers and harbors approved March 3, 1875.

The distance covered by this examination is 62 miles, and in this distance the fall of the river is 526 feet, which is a little more than 100 feet greater than the entire fall of the Ohio River from Pittsburgh to Cairo. The average rate of fall on this part of the Louisa Fork is 8½ feet per mile.

The country is very sparsely settled, the majority of the inhabitants being engaged in cutting and rafting logs to the Ohio. The only improvements that they request are such as will help the rafting interest, such as straightening sharp bends, closing duplicate channels, cutting down trees that overhang the channel, and removing large rocks in the bed of the river. This work is so scattered in location and so uncertain in amount as to make accurate estimates impossible. Mr. Bell submits an estimate of $18,000, and suggests that at least $3,000 ought to be expended in improving the channel at the worst places.

I am satisfied that any moderate sum that Congress might see fit to appropriate could be used to advantage, provided it did not exceed the larger sum named above.

An improvement by locks and dams would not be justified by the present needs of commerce.

Respectfully, your obedient servant,

WM. E. MERRILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

REPORT OF MR. JAMES E. BELL, ASSISTANT ENGINEER.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, December 15, 1875.

SIR: I have the honor to submit the following report of the reconnaissance of the Louisa Fork of the Big Sandy River, from Piketon, Ky., to the mouth of Dismal Creek, in Buchanan County, Virginia, assigned to me by your orders July 14, 1875.

The lower portion of Louisa Fork, as far up as Piketon, was surveyed during the fall of 1874, under your instructions, and in a report, made last February, are given a general description of that stream and a statement of its commercial importance.

The reconnaissance of the upper portion of Louisa Fork, as designated in your orders, was begun at the mouth of Dismal Creek soon after the cessation of the continuous rains of last July, when the fork had fallen to a safe navigable stage.

The Louisa Fork rises in a ridge of the Cumberland Mountains in Buchanan County, Virginia, and flows in a northwesterly direction, with a very tortuous course, through Buchanan County, Virginia, and Pike, Johnson, and Lawrence Counties, Kentucky; opposite the town of Louisa, in Lawrence County, Kentucky, and about 26 miles from the Ohio River, it unites with the Tug Fork, and the two form the Big Sandy River.

The range of mountains that forms the boundary between Buchanan and Tazewell Counties, Virginia, is the water-shed of Louisa Fork and of Clinch River, an important tributary of the Tennessee, and it is known in geography as the Clinch range of the

Appalachian Mountain system. Another range of this same system, which forms the dividing-line between Virginia and West Virginia, is the water-shed of the two forks of the Big Sandy.

That portion of the Clinch range which gives its water to the Louisa Fork is known in Buchanan and adjacent Virginia counties as the Sandy Ridge.

The survey was begun at the mouth of Dismal Creek, about 15 miles from the head-waters of the Louisa Fork, and the elevation of low water at this place is 687.506 feet above low-water mark of the Ohio River at Catlettsburgh, Ky., or 1,175.868 feet above mean ocean tide.

The mountainous section which is drained by the Louisa Fork is divided into ridges by its many long and sinuous tributaries, whose sources are upon these ridges, at distances of from 2 to 50 miles from the main stream; they are fed almost continually throughout the year by numerous mountain-springs, which become, especially during dry seasons, the only means of maintaining the supply of water in the fork.

The Louisa Fork is, in many respects, the most important tributary of the Big Sandy River. Its basin is the widest, longest, and the most fertile. Its valley is the richest, both in mineral and in agricultural resources. It is the only outlet for the trade of this section of Eastern Kentucky.

The bottom-lands, varying in width from 200 to 1,000 feet, extend in a nearly level plain, generally above ordinary high-water mark, from the bank of the fork to the foot of the rocky hills on each side. The difference of elevation between the extreme stages of high and low water diminishes as the fork is ascended, and it often happens that, when the high bottom-lands near Piketon are inundated, the low lands in the immediate vicinity of Grundy are free from overflow.

The area drained by that portion of the Louisa Fork lying above Piketon is about 1,200 square miles. As there are no records of the amount of rain-fall on this area, it is impossible to estimate the average annual discharge of the fork, but from the fact the rises are very sudden, and at times reach 51 feet above low water at Piketon, it is a fair inference that a very large portion of the downfall is carried off by the river.

The area under cultivation is exceedingly small, the greater portion of the basin being made up of precipitous hills, thickly covered with trees. The bed of the river is rocky, and its slope is so steep as to carry off water with great rapidity.

The valley of the Louisa Fork is crooked, rough, and narrow, and is in many places confined, for a considerable distance, to a narrow passage between rocky hills. The stream meanders from side to side of its valley, alternately approaching the river hills on one side and washing their bases on the other, thus affording a comparatively easy and unobstructed land-passage on one side, and effectually preventing such a road on the other. The banks of the stream between Piketon and Russell Fork, about 12 miles above, are composed mostly of sand; but in some places they contain loose rock and gravel, and in others they are the solid cliffs of the bordering hills. Above Russell Fork the banks contain very little sand or mud, being generally composed of solid rock, loose rock, or gravel. The solid-rock banks are found at those places where the mountain-sides are washed by the fork, which occurs alternately on the two sides of the stream, usually at the bends, where the rock walls rise perpendicularly many feet above the water. The bed of the stream, up to Russell Fork, is composed mostly of a deposit of fine sand; but in some places, especially near the shoals, we find loose rock and gravel. Above Russell Fork the bed-rock appears almost everywhere. The sand bottoms near the mouths of tributaries and the coarse gravel-beds of shoals are, no doubt, but the scanty coverings of a rock bottom. The pools are of various lengths, depths, and widths. The longest are found below Russell Fork, those above being much shorter and more numerous. The shoals are natural dams for holding water in the pools, and the latter are the reservoirs that supply the Big Sandy River during dry seasons, as the many tributaries below Piketon only contribute in rainy seasons toward maintaining the river's supply. The shoals, which are very numerous, very steep, and very long, are generally occasioned by a reef of rocks, together with more or less loose rock or coarse gravel, running entirely across the bed of the fork. They increase in steepness and length as the stream is ascended, so much so, that in several places a succession of shoals, with intervening short pools of deep water, are found, extending over a distance of one or more miles.

During freshets the ripples entirely disappear, and the fork becomes a torrent of mad waters, laden to its maximum capacity with sediment. The Louisa Fork, up to the mouth of Russell Fork, has nearly a uniform width of 350 feet, but above this point it varies in width from 100 to 180 feet, except in the immediate vicinity of the islands, where it sometimes spreads to 250 feet or more.

The river-hills increase in height as the fork is ascended, their average height above low-water mark being about 700 feet.

The entire population of the basin of Louisa Fork above Piketon, according to census returns of 1870, is about 1,400, which is an average of about 13 persons to each square mile drained.

Piketon is, in every respect, the most important town in the mountain section of Eastern Kentucky. Grundy, the only other town on the upper portion of this fork, is an isolated village of no importance, hemmed in on all sides by high mountains.

The length of the Louisa Fork, from Piketon to the mouth of Dismal Creek, is 61 miles, and the total distance from Catlettsburgh, Ky., (at the mouth of the Big Sandy River,) to Dismal Creek is 165 miles. The average rise up to Russell Fork is 1.87 feet per mile; above this point it increases to 9.82 feet per mile.

GENERAL REMARKS.

The following list gives the approximate lengths of the principal tributaries of Louisa Fork:

	Miles.
Island Creek	8
Shelby Creek	50
Russell Fork	80
Big Creek	7
Hurricane Creek	20
Bull Creek	8
Big Prater Creek	8
Dismal Creek	30

The Russell Fork is the longest and most important feeder of Louisa Fork, and it flows through a gap in the Cumberland Mountains over a series of rock-bottomed falls between high perpendicular banks. The valley of this fork, as well as those of the other tributaries, has similar general features to that of the main stream.

The water-supply of the Louisa Fork was approximately gauged at two points when the stream was in different conditions. The discharge at Vance Shoal was taken when the depth of the water was 6 feet, or 2 feet above rafting stage, and still rising, and it gave about 2.758 cubic feet per second, with a velocity of 4 miles per hour. The gauging at Conaway Shoal, when the fork was 2 feet above low-water mark, or below rafting stage, gave a discharge of 360 cubic feet per second.

The duration and the kind of navigation of the Louisa Fork during each season are as follows: Steamboat navigation from the mouth of Piketon, Ky., is practicable about four months each year, and at other times, except when the stream is at its lowest mark, trade is continued successfully by means of "push-boats."

The steamboats that navigate this fork are flat-bottomed, with square-raked bows. They draw 30 inches with a load of 30 tons, and are 65 feet long, with 10 feet beam. The highest point usually reached by them is Piketon, but occasionally during the season just past they ascended to the mouth of Russell Fork, and one trip was made about 4 miles up this fork. Steamboats find great difficulty in getting to Russell Fork, especially in crossing the shoals, where the swiftness of the water is too great for the propelling power of the boat, and they are compelled to warp up by capstan and line. The shortness of the distance through which the great descents occur, and the increase in velocity at every increase of volume, make navigation so difficult, that, during freshets, the fork cannot be ascended at all. The highest point ever reached, even by "push-boats," was Hackney's Creek, about 38 miles above Piketon, and, as this happened many years ago, it is supposable that the difficulties in passing the shoals and the uncertain stages of water in the fork prevented the continuation of that laborious mode of transportation to any great distance above Piketon. The people, as far up as the State-line, do all their transportation in canoes, when the water will permit, and at other times their commodities are either packed by mules and horses or hauled in wagons. In Kentucky there is a narrow dirt-road following the meanderings of the fork, on one side or the other, throughout its entire length; but it is not graded nor raised above the natural surface, and consequently at every freshet it is washed away in many places, generally where it crosses the tributaries. In Virginia, however, there is a macadamized turnpike in good repair, and generally above high-water mark.

The only practical or profitable use of the Louisa Fork is for rafting logs at certain stages of water. They are formed into half rafts, 60 feet long and from 18 to 20 feet wide, and containing about 800 feet of lumber. These rafts consist almost entirely of poplar logs, averaging not over 30 inches in diameter; but occasionally a small raft of walnut logs is taken out. The heavier woods and logs of poplar of a greater diameter than 30 inches are but seldom rafted, on account of the slight depth of water during the rafting stage. This stage occurs at irregular intervals during the winter and spring, the maximum depth being 4 feet above low-water mark and the minimum 3 feet; this gives the raftsmen in the immediate vicinity of Grundy a margin of 12 inches for their work. A rise of 3 feet at Grundy gives sufficient water to float the deepest raft over the shallowest shoal in Kentucky, and a rise of 4 feet at the same point, provided it comes only from above, gives the maximum limit of a safe rafting stage. When the rise is general in all the tributaries, with the same depth of 4 feet at Grundy, rafting is impossible, because the velocity of the stream becomes so great that the rafts are unmanageable and cannot be kept in the channel, either in rounding the sharp bends or in passing other obstructions.

The mercantile products of the valleys of the upper portion of Louisa Fork and its tributaries, especially in Kentucky, go overland to Piketon, to be shipped, according to the season, either by steamboat or push-boat to markets on the Ohio River. The principal exports, besides lumber, are the usual accumulations of country stores, such as medicinal herbs, skins, furs, and dried fruit.

Pike County contains about 50 square miles, and is drained by many tributaries of the Louisa Fork which flow through it. The taxable property of this county is estimated at $2,000,000, and it is more populous than any other of the Big Sandy Valley counties.

The following statistics of the products of Pike County for the year 1874, and of their value, were kindly furnished by Hon. John Dils, of Piketon, Ky.:

	Value.
Corn, 500,000 bushels	$300,000
Wheat, 30,000 bushels	30,000
Orts, 25,000 bushels	11,250
Dried peaches, 40,000 bushels	40,000
Dried apples, 10,000 bushels	10,000
Medicinal herbs, bees-wax, honey, furs, skins, &c	25,000
Lumber	75,000
Total	491,250

The exports will average about $250,000 each year, and it is estimated that the imports largely exceed the value of exports, although nothing definite can be obtained concerning them from the merchants. Mr. Dils says that a safe and cheap means of transportation would more than double the resources of this country.

The Virginia basin of this fork and the adjoining sections in West Virginia have an overland outlet for trade at Saltsville, Va., a station on a branch of the railroad from Lynchburgh to Knoxville. The expense of hauling merchandise 60 miles or more over rough mountain-roads greatly increases the first cost of the goods. The aggregate values of the exports and imports were kindly furnished by Mr. John N. Watkins, of Grundy, Va. He places them at $400,000 per annum. This trade would naturally flow to the centers of supply on the Ohio River, were there any means of transportation to those markets.

Lumber in the shape of logs is the chief article of export, but many other products, such as herbs, skins, wool, feathers, and dried fruit, are yearly shipped in large quantities.

The bottom-lands are generally planted in corn, but only in such quantities as to supply the inhabitants and the cattle that are employed in lumbering.

The valleys are very well adapted both in climate and in soil to fruit-growing, and it is a very rare occurrence for orchards to fail to yield an average crop each year. The soil is also well adapted to the culture of tobacco, but at present only enough is raised for home consumption. Stock-raising is not carried on to any great extent, although there are excellent grazing-lands in this valley covered with blue-grass of spontaneous growth. The mountain-sides are covered with dense forests of valuable trees, which have the appearance of being able to furnish an almost inexhaustible supply of timber.

The forests on the banks of the upper portion of Louisa Fork have for years past furnished a large amount of the choicest and best lumber for the manufactories on the Ohio River. Although large quantities of timber have been taken from this section, there yet remain many mountains whose river-slopes are covered with excellent trees which can readily be put into the water at a small expense.

The great fall in many of the shoals gives sufficient power for milling purposes, and five mills at different shoals have availed themselves of these advantages for grinding grain for the surrounding country. These rudely-constructed grist-mills, whose average yield, at the most, is about 20 bushels daily, often have saw-mills in connection with them, but their capacities are only sufficient for sawing what lumber is required for the limited trade of the country.

The rafting of logs has engaged the inhabitants of this entire valley to such an extent that their farms are left uncultivated, or, even if cultivation is attempted, it is poorly done, and is limited to what is barely sufficient for home-wants. It is for these reasons that there is such a scarcity of farm-products. A company was formed a few years ago, called the Pennsylvania Company, to go extensively into the rafting business. They erected "booms" in Russell Fork, near its mouth, for catching the logs thrown into it from the mountain-sides above; but the many disasters that attended this manner of storing logs, due to the sudden freshets washing away the "booms," compelled the abandonment of the enterprise after considerable loss had been sustained.

A new company has taken possession of the old company's effects, and intend to continue to raft logs to the Ohio River. There is no manufacturing of wooden ware in this valley.

This entire country is geologically situated in the Appalachian region of the Carboniferous age, which includes the coal-measures of Western Pennsylvania, West Virginia, Buchanan and Wise Counties, Virginia, and the eastern part of Kentucky.

There has not been any special geological examination of this country, and all that is known concerning its formation has been learned by means of the outcroppings along the roads and creeks, or from similar formations of this same period in other localities where investigations have been made. The exposures at various places show many fine developments of coal of excellent quality and in beds of varying thickness.

The iron-ores are not of sufficient thickness or abundance to require special notice.

The Sandy Ridge is a geological division between the limestone and sandstone formation of the Appalachian region, and on its western side, which is drained by the Louisa Fork, it contains many coarse grayish conglomerates and sandstones.

The relations of the sandstones, shales, &c., that alternate with the coal-beds in this section are but partly understood. In the vicinity of Grundy, and in other parts of the valley, a buhr-stone, a cellular, flinty, and siliceous rock of a white color, occurs in beds several feet thick. The millers of this valley use it in their mills, and say that while it has no superior for grinding corn, it is not as good as the French buhr-stone for wheat.

It will be proper to describe, in a general manner, the obstacles that always give the raftsmen trouble during the rafting season. The great demand for good lumber induced the raftsmen to procure their supplies from the heavily-wooded country above Piketon, but before they could be transported, many of the sharpest bends had to be straightened, and some of the more dangerous rocks had to be removed from the channel. The amount of work done in improving the channel was the minimum that would at all answer the purpose. The bends are still serious obstacles to rafting, as it is very difficult for the raftsmen to keep their rafts from striking the shores, more especially where, as is often the case, there is a shoal just above the bend. The difficulty is further increased by the danger of being "stove-up" on the rocks that are often found in these places. The abundance of islands is a peculiar feature of the upper portion of Louisa Fork. They are generally found in clusters, with narrow and shallow chutes between them, thus spreading the stream over a wide area, and so reducing the volume in the main chute as to make it narrow and shallow. In Kentucky the shoals are generally very shallow, and it would be very advantageous if they could be excavated a few feet, in order to let rafts float over them at a lower stage than is now available.

During the rafting season the raftsmen are not seriously inconvenienced by the mill-dams, nor by leaning trees or snags, the latter being only exposed at low water.

A general improvement of the fork by closing island chutes, widening and straightening the channel at a number of difficult places, and removing rocks and other obstructions, would lengthen the rafting season, and would permit the running out of rafts with less expense and labor and with greater safety than ever before. The following estimate is approximately the cost of improving the upper portion of Louisa Fork.

In many places the materials taken from the shoals and islands can be used advantageously in closing the chutes at no further increase of expense. In almost all cases the work would be "dry work."

Closing 8 chutes by dams of brush and stone, at $200	$1, 600
Straightening 9 bends by cutting off points, at $400	3, 600
18,000 cubic yards earth-excavation at shoals, at 50 cents	9, 000
600 cubic yards rock-excavation at shoals, at $2	1, 200
Removing overhanging trees	1, 000
	16, 400
Contingencies, &c., 10 per cent	1, 640
Total cost	18 040

It would be a great benefit to lumber-navigation if any sum of money were appropriated and judiciously expended in straightening the sharpest bends and in removing the worst obstructions. If it does not seem advisable to make the expenditure detailed above, it is respectfully suggested that at least $3,000 ought to be expended in improving the channel at the worst places.

The improvement recommended of the Louisa Fork, above Piketon, to which this report is limited, is only for the removal of those serious obstructions that are constantly met in transporting lumber during the rafting stage, it being scarcely probable that any improvement, except by locks and dams, would benefit navigation in this fork to such an extent as to induce merchants near the headwaters to open trade communications by means of boats. The proposed improvement will probably permit push-boats to ascend the fork higher than ever before; but they will certainly meet, in the ascension, even when the stream is most favorable for navigation, many serious obstructions, that will have a tendency to make this mode of transportation unfavorable, as well as unprofitable. The coal-deposits would not be any inducement for improving this fork by any of the known means, as excellent beds of this formation are found nearer the mouth of the river.

It would be an unwise expenditure of money to improve the upper portion of Louisa Fork by means of locks and dams, even if the business of the valley were of such magnitude as to require it, as long as the fork below Piketon remains in its present unnavigable condition.

The following table gives the elevations and distances of various points on the Louisa Fork of the Big Sandy River.

The elevations are only for the lower ends of the shoals; but the rise of each shoal and its length are given in separate columns.

Louisa Fork of the Big Sandy River.

Miles from Catlettsburgh.	Name.	Elevation in feet above low water, Ohio River, at Catlettsburgh.	Elevation in feet above mean ocean-level.	Rise in feet.	Length in feet.	Remarks.
....	Catlettsburgh..........	....	488. 362	....	......	
112. 50	Piketon, Ky.:					Piketon, the county-seat of Pike County, is situated on a plateau about 51 feet above low-water mark, and is, except in extreme freshets, free from inundation.
	Low-water mark.....	161. 198	649. 560	....	....	
	High-water mark of 1863.	212. 259	701. 321	....	....	
113. 00	Harrell Branch Shoal.	161. 198	649. 560	1. 036	300	
114. 75	Island Creek Shoal ..	162. 234	650. 596	1. 766	500	
115. 10	Moore's Shoal	164. 000	652. 362	0. 981	300	
116. 50	Marion Sword's Shoal	165. 019	653. 371	1. 482	300	
117. 75	Porter Shoal.	166. 500	654. 862	5. 462	2, 640	
118. 60	Turnhole Shoal	171. 962	660. 324	1. 000	300	
120. 25	Sword's Mill Shoal ..	172. 962	661. 324	2. 645	600	
120. 80	Shelby Creek Shoal..	175. 607	663. 969	0. 413	300	
121. 50	Cloe Shoal	176. 020	664. 382	1. 510	600	
122. 90	Narrow Hollow Shoal	177. 530	664. 892	1. 294	600	
123. 20	Justus Shoal..........	178. 824	667. 186	0. 603	201	
123. 90	Greasy Shoal	179. 427	667. 789	0. 652	300	
124. 67	Fork's Shoal..........	180. 075	668. 437	3. 893	450	
125. 25	Fish-Trap Shoal	183. 968	671. 330	2. 421	300	
125. 70	Shoal	186. 389	673. 751	2. 010	300	
125. 90	Pompey Shoal........	188. 399	676. 761	2. 210	300	
127. 60	Crossing Shoal........	196. 000	684. 362	2. 329	200	
128. 10	Sloan's Shoal	198. 329	686. 691	3. 107	600	
129. 30	Blackburn Shoal.....	201. 436	689. 798	2. 419	900	
130. 87	Abner's Mill Shoal ..	205. 375	693. 737	3. 938	300	
133. 13	Grapevine Shoal.....	218. 417	706. 779	2. 000	200	
134. 62	Andy's Shoal	228. 569	716. 931	3. 451	900	
135. 87	Miller Creek Shoal ..	235. 470	723. 832	2. 559	1, 200	
136. 62	Rowe Shoal	238. 569	726. 931	1. 870	600	
137. 38	Crossing Shoal.......	240. 439	728. 801	4. 518	1, 200	State road crosses shoal at this point.
138. 13	Lick Shoal......... .	246. 957	735. 319	3. 505	600	
139. 50	Stump's Island Shoal.	252. 460	740. 822	5. 202	900	Allen Rock is at foot of this shoal, and it contains about 50 cubic yards.
140. 95	Elkfoot Shoal	263. 085	751. 447	4. 742	300	
141. 75	Field's Mill Shoal....	268. 227	756. 589	7. 521	300	There is a grist-mill at the head of this shoal.
143. 00	Hunt's Shoal.........	276. 879	765. 141	2. 000	500	
143. 62	Big Creek Shoal	288. 324	776. 686	4. 464	900	Shoal is narrow and shallow.
144. 75	Fish-Trap Shoal	293. 828	782. 190	5. 252	400	
145. 75	Rocky Hollow Shoal	301. 830	790. 192	3. 324	750	
146. 50	Cuba Islands Shoal ..	305. 154	793. 516	1. 917	200	Stream is shallow at this point.
146. 75	Long Shoal	307. 071	795. 433	6. 267	750	
147. 00	Fed's Creek Shoal....	313. 335	801. 697	4. 819	900	
148. 50	Rocky Shoal	328. 476	816. 838	4. 961	900	
149. 10	Card Creek Shoal....	333. 437	821. 799	2. 847	600	This is a very shallow shoal.
150. 87	Hackney's Shoal ..	348. 773	837. 135	4. 467	320	
151. 16	State-Line Branch Shoal.	354. 742	843. 104	4. 936	600	
151. 35	Kentucky and Virginia State line.	....	....	....	......	
151. 40	Collins Shoal.........	359. 678	848. 040	3. 740	350	
151. 84	Buckeye Shoal.......	363. 418	853. 780	4. 145	650	
152. 25	Mill Shoal	367. 563	855. 925	4. 500	400	

Louisa Fork of the Big Sandy River—Continued.

Miles from Catlettsburgh.	Name.	Elevation in feet above low water, Ohio River, at Catlettsburgh.	Elevation in feet above mean ocean-level.	Rise in feet.	Length in feet.	Remarks.
152.60	Conaway Shoal	372.063	860.425	6.887	600	There are three large rocks in this shoal.
153.12	Fish-Trap Shoal	378.950	867.312	5.470	1,000	
154.00	Rocklick Shoal	388.654	877.016	10.032	600	Point of rocks on left is very dangerous to rafting.
155.00	Home Shoal..........	405.405	893.767	6.982	600	
156.06	Louisa Bend Shoal...	423.318	911.680	8.955	700	This bend gives much trouble in passing.
156.78	Linn Camp Shoal....	436.402	924.764	9.560	900	
157.75	Bob Rock Shoal......	449.600	937.962	5.098	250	There is a large rock at foot of this shoal, called Bob Rock; its dimensions are 10 by 15 by 12 feet, and it is a serious obstacle to raftsmen; there are five other large rocks in this shoal.
157.87	Bull Shoal	454.698	943.060	8.015	300	This shoal is narrow, shallow, and filled with rock.
158.20	Fording Shoal	462.713	951.075	4.155	400	Point on left is very sharp.
158.50	Clevinger Mill Shoal	466.868	955.230	5.732	300	
158.70	David Stiltner Shoal.	472.600	960.962	4.706	300	Bend on left dangerous.
159.50	Mill Shoal	477.306	965.668	6.386	1,000	Shoal contains large rocks.
159.87	Jared Stiltner Shoal .	484.500	972.822	3.417	700	
160.00	Elizabeth Bend Shoal	487.917	976.279	6.161	900	Bend is very sharp and contains many large rocks.
161.10	Looney Shoal	498.980	987.342	3.640	300	
161.25	Ford's Shoal	502.620	990.982	2.509	200	Point ought to be cut off.
161.42	Fish-Trap Shoal	505.129	993.491	4.381	900	
161.87	Clevinger Shoal......	514.765	1,003.127	4.461	800	Bend too sharp at head of shoal.
162.35	Clevinger Rock Shoal	519.226	1,007.588	6.457	900	This shoal contains many large rocks.
162.68	Otter Slide Shoal....	525.683	1,014.045	4.613	500	Many large rocks have slid into the stream at this shoal; bend on right is very sharp.
163.45	Ratliff's Shoal	530.296	1,018.658	4.883	200	
163.65	Fish-Trap Shoal	539.445	1,027.807	3.834	900	This shoal contains some large rocks.
164.13	Grundy Shoal........	543.279	1,031.641	14,726	3,300	There are many large rocks in this shoal.
164.75	Grundy:					
	Low-water mark.....	558.005	1,046.367	....	......	
	High-water mark ...	568.065	1,056.427	....	......	
165.50	Mill Shoal	558.005	1,046.367	10.005	1,250	
165.87	Higbitt's Shoal	568.000	1,056.362	7.500	950	
166.25	Barn Shoal..........	575.500	1,063.862	4.150	900	
166.50	Watkins Shoal.......	579.650	1,068.012	4.650	1,200	
166.90	Smith Bend Shoal....	584.300	1,072.662	5.260	1,000	
167.75	Rattle-Trap Shoal....	598.560	1,077.922	6.950	400	
168.60	Matny Shoal.........	596.510	1,084.872	7.250	1,200	
169.65	Vance Shoal	603.760	1,092.122	16.000	2,600	
170.65	Prator Shoal.........	619.760	1,108.122	15.490	1,250	
171.65	Mulberry Shoal	535.250	1,123.612	10.000	1,350	
172.10	Ratliff's Mill Shoal...	645.250	1,133.612	10.506	900	
172.50	Dismal Creek Shoals	655.756	1,144.118	31.750	9,800	A series of shoals with many large rocks, and separated by short pools of deep water.
174.35	Dismal Creek........	687.506	1,175.868	....	......	

Three maps, with profiles, accompany this report. The horizontal scale is 1 inch to 2,000 feet, and the vertical scale is 1 inch to 10 feet.

Respectfully submitted.

JAMES E. BELL,
Assistant Engineer.

Maj. WILLIAM E. MERRILL,
Corps of Engineers, U. S. A.

R 9.

EXAMINATION OF THE ALLEGHENY RIVER, BELOW FREEPORT, AND SURVEY OF THE ALLEGHENY RIVER, NEAR PITTSBURGH.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, March 9, 1876.

GENERAL: I have the honor herewith to transmit the report on the "Allegheny River below Freeport, Pa.," and on the "Allegheny River near Pittsburgh, Pa.," ordered in the river and harbor bill approved March 3, 1875. These surveys were assigned to my charge by your letter of March 22, 1875. The instructions which I received directed me to make a careful survey of so much of the Allegheny River as lay within the limits of the city of Pittsburgh, and to make a reconnaissance survey of that portion between the upper city limits and Freeport. I assigned the charge of these surveys to Lieut. F. A. Mahan, Corps of Engineers, who was assisted by I. V. Hoag, jr., civil engineer. Lieutent Mahan's report is herewith forwarded. It has been kept back until now to await the completion of the maps.

The distance from Freeport to the mouth of the Allegheny is a little more than 30 miles, and to the city limits of Pittsburgh is nearly 22 miles. The length of river within the corporation limits of Pittsburgh is 8¼ miles. This distance was surveyed with great care, and has been platted on the scale of 1 inch to 200 feet, which is the same scale as that adopted for the survey of the Monongahela and the Ohio portions of the harbor of Pittsburgh, made by Lieutenant Mahan in 1874. By combining these two maps a complete map can be obtained of the water-front of Pittsburgh, and it will also include all the water-front of Allegheny City, except the portion opposite Brunot's Island, which was surveyed in 1870. Therefore our maps of the harbors of these important river cities are now complete.

The fall of the Allegheny between Freeport and its mouth, as shown by the profile, is 52.14 feet. On account of the extraordinary rains and floods of July and August, the reconnoitering party engaged on the piece of river lying above Pittsburgh could not obtain a low-water profile, as the least water found on the shoals during the time of the examination was 3 feet. The water-surface on this part of the line has been platted without reduction to low water, as such reduction could not be made with accuracy. It is well known that the fall at the head of a natural pool is always much greater than at its foot, and that the surface at ripples or bars is less affected by a decrease in the supply of water than the surfaces of pools. However a radical improvement of the navigation that will give adequate depths at all times will necessitate permanent or movable dams, and for such works an exact knowledge of the low-water profile is not necessary. The survey of that part of the river within the city limits was made more carefully, and it shows the low-water surface.

The chief articles of commerce on the Allegheny River are lumber and petroleum. I am satisfied that the lumber interest would prefer the river in its present condition, as they cannot do any rafting except when the small streams near headwaters are full; and when this is the case the main river has a sufficiency of water, and no time is lost in passing through locks, nor are they compelled to steer their rafts through navigation passes, which, however wide they may be, must yet of necessity be less wide than the unobstructed river.

As regards the wishes of the petroleum or oil interest as to the river improvement, I cannot speak with certainty, as no person in this interest has communicated with me on this subject; but Lieutenant Mahan states that there is a general desire for slackwater on the part of the bargemen who transport oil to Pittsburgh. Petroleum being a fluid product, is capable of transportation by gravity, and this quality has already been largely utilized by the construction of "pipe lines," by which it is made to flow through long lines of pipe just as water is delivered in cities. The viscosity of the fluid uses up the initial head in a relatively short distance; but by establishing ralays of pumps the head can be regained from time to time until the fluid reaches its destination.

This system has been used for several years in delivering oil for short distances; but it is only lately that attempts have been made to deliver in this manner at Pittsburgh. Whether this new method of transportation will prove a success and put an end to transportation of oil in barges, it would be premature to predict; but it would seem to be prudent to wait a short time to ascertain this fact before incurring expenses that might prove unnecessary and unremunerative. With these views, I do not feel called upon to recommend any work for the present on the Allegheny above the limits of Pittsburgh.

Within the city limits there is a work that is important in itself as a very necessary improvement of the Allegheny Harbor of Pittsburgh. This is the construction of a lock and dam about midway of the Allegheny Harbor. This work will necessarily be the first to be built in case Congress should decide to improve the navigation of the Allegheny River, and the doubts that may fairly arise as to the advisability of the other dams do not apply to this one, as there are strong independent reasons for this work. From its mouth to the city limits, a distance of 8.3 miles, the Allegheny is lined on both sides with important industrial establishments, mostly connected with the iron or petroleum industries. These establishments urgently call for permanent water-communication with the Ohio, and the great value of their products and the value to the whole country of the productions of our most important manufacturing center seem to justify the necessary expenditure, even though the river above should be neglected.

The proper site for this dam is at the 16th (Mechanics') Street Bridge. This site is definitely fixed by the fact that the movable dam projected on the Ohio at Davis's Island will give 6 feet of water at all stages up to this point. This, therefore, is the proper location for the next dam, on the supposition that 6 feet is established as the minimum to be allowed anywhere in Pittsburgh Harbor.

It is my opinion that the dam in question should be a movable dam, but that the width of navigable pass need not exceed 200 feet, as the absence of navigation by large fleets will make this width ample for all purposes that can now be foreseen, and for the additional reason that there would be no serious difficulty in widening this pass at a future date should it be found necessary.

The best size of lock to be used in connection with this dam depends entirely upon the kind of steamboats and barges used on the Allegheny and that probably will be used after this dam is built. This is a study that had better be postponed until actual construction is probable, but for the purposes of this estimate, I will assume that the lock should be of the same size as the one now under construction on the Monongahela, near Morgantown, namely: 200 feet between mitre-sills, and 50 feet in clear width.

The limited allotment for the survey, and the necessity of preparing the maps before selecting the sites for the dams, made it impracticable to determine the exact character of foundation by boring. From the information that was obtained I am led to believe that all the sites are overlain with gravel to such a depth as to prevent reaching rock at moderate cost. I therefore make my estimates on the supposition of a gravel foundation.

ONE MOVABLE DAM AND LOCK IN HARBOR OF PITTSBURGH.

One lock, 200 by 50	$65,000
Navigable pass, 200 feet, at $226.91	45,382
Low wier, 350 feet, at $212.08	74,228
High wier, 350 feet, at $112.49	39,371
Two piers, at $5,351	10,702
Masonry abutment	10,375
	245,058
Contingencies, 10 per cent	24,506
	269,564

For reference, I add an approximate estimate of improving the river from its mouth to Freeport by five permanent dams, with an average lift of 11 feet.

IMPROVEMENT FROM MOUTH TO FREEPORT BY PERMANENT DAMS.

5 locks, 200 by 50	$325,000
5 masonry abutments, at $4,500	22,500
5,355 feet of timber dam, at $65	348,075
	695,575
Contingencies and engineering, 10 per cent	69,557
	765,132

It will be seen from the above that a permanent dam within the city limits would not cost more than 55 per cent. of a movable dam. Under these circumstances the choice between the two might very properly be left to the parties most interested.

This report is accompanied by a map of the portion of river surveyed. It is in two parts; one embracing that part of the river within the limits of the city of Pittsburgh, and the other that portion above the city.

Respectfully submitted.

WM. E. MERRILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

REPORT OF LIEUT F. A. MAHAN, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, December 15, 1875.

SIR: I have the honor to report the following result of the work done on the Allegheny River, Pennsylvania, during the past summer.

Your instructions to me were to go to Pittsburgh, Pa., and, after making up my party, to make a reconnaissance and survey of the Allegheny River from Freeport to the mouth. The reconnaissance was to cover that part of the river outside of the limits of the city of Pittsburgh, and the survey was to cover the part within those limits.

In compliance with your orders, I left Cincinnati on the 9th of July and arrived in Pittsburgh on the 10th. On my arrival I found that my assistant, Mr. Hoag, had partly organized the party, of which I completed the organization. The party was divided into two sections, I taking direct charge of the first and Mr. Hoag of the second.

The work of my section consisted in determining the fall of the river between Freeport and the mouth, and in making the reconnaissance between Freeport and Slade's Run, which is the boundary-line of the city of Pittsburgh. Mr. Hoag's party had the survey and soundings between Slade's Run and the mouth. The length of the river covered by the reconnaissance was 21.7 miles, and that covered by the survey was 8.3 miles.

Work was very much impeded by the constant rains and high water of the latter part of July and the beginning of August. As an example of this I will state the experience of my party in running the levels down the river: We began leveling on Tuesday morning, July 13, and ended at noon on Friday, July 23, during which time we should have had 112 working-hours, but, as a matter of fact, it rained for 72 hours, and we worked but 40 hours. Consequently I did not complete my work until a month later than I expected. In making out my estimate of the amount required to do the work, I allowed for only 33 per cent. of the time being lost by rains; but when that percentage was increased to 64 in the beginning of the season it will be readily seen that the last part of the work had to be very much hurried in order that the funds provided for the work should not be overrun. Owing to these causes the results of my work are not as satisfactory as I should wish to have them, especially in almost the most important point, viz, in the determination of the fall of the river, which is not the low water fall, as it should be. However, I think that for all purposes of a reconnaissance it is a sufficiently close approximation, and is certainly serviceable in case any future work should be done on the Allegheny.

The Allegheny River rises in Potter County, Pennsylvania, from whence it pursues a northwesterly course to Salamanca, N. Y.; thence it runs southwest to Franklin; thence to Mahoning it runs southeast; thence to Pittsburgh it runs southwest again.

A very steady source of its water supply is to be found in Lake Chautauqua and the neighboring ponds, in Chautauqua County, New York. These bodies empty into the river through Conewango Creek, which is the first of the principal tributaries of the Allegheny, which it joins at Warren.

The principal tributaries are Conewango Creek, just mentioned; Tionesta Creek, joining at Tionesta; Oil Creek, joining at Oil City; Red Bank Creek, joining at Red Bank Furnace; the Clarion River, joining at Foxburg; Mahoning Creek, joining at Mahoning; and the Kiskiminetis (or Kiskiminitas) River, joining just above Freeport. The headwaters of the Kiskiminetis are not far from the Castleman River, the main tributary of the Youghiogheny River.

As the act of Congress approved March 3, 1875, under which this examination was made, requires it to extend from Freeport to the mouth of the river, I shall only consider so much of the river as is found below the mouth of the Kiskiminetis.

The general course of this part of the river is southwest. The bed is composed almost wholly of broken sandstone rock and of gravel, with here and there a little sand and mud. Wherever the rock strata are visible on either side of the river they are almost horizontal, consequently I infer that the true bed of the river is of rock at no great depth below the apparent bottom, but of this I cannot be sure, as I made no borings.

The river is composed alternately of deep pools and ripples, the latter having steep falls as a rule. The worst ripples are Dock Ripple, just opposite the mouth of the Kiskiminetis, and Garrison Ripple, at the head of Herr's Island. The channel in each of these is hard to follow; the water is shallow and the current swift. Poketo (pronounced Puck'-e-ty) Ripple has a very swift current, but the water is quite deep and the channel is easily followed. The ripples at Nine-Mile Island and at Six-Mile Island are shallow, and in the channel of the latter are found large stones that make it dangerous for passing vessels. In all those mentioned above, there is a marked surface-break, but those that I shall next name are without this break, and cannot, therefore, I think, be considered really as ripples, although they are so called, viz: Sligo Ripple, Jack's Ripple, Lockhart's Ripple, and the ripples at Metzgar and at Twelve-Mile Island.

The pools have plenty of water, being in every case very deep, there being many places where, in low water, there is no bottom at 10 feet, and in one pool known as Logan's Eddy, there is one stretch where there is no bottom at 16 feet, and another where there is none at 25 feet.

The country along the river is not well adapted to agriculture, owing to the small amount of space occupied by the bottom-lands and to quantities of stone found in the ground near the hills, nor does it appear to possess any particular mineral wealth, although I did see a great many quarries of good sandstone that looked as though it might make a good building material.

The towns are all small, Freeport being the largest. It is here that the railroad to Butler branches off from the West Pennsylvania Railroad. The industries here are oil-refining, barrel making, lumber-sawing, and whisky-distilling; there being, so far as I could find, one refinery, one cooper-shop, one saw-mill, and one distillery. Natrona, the next town below Freeport, is the seat of the Pennsylvania Salt Company's works.

At Tarentum is a saw-mill and a planing-mill, and a little below is an oil-refinery and a cooper-shop. At the remaining towns I saw nothing in the way of manufacturing interest.

There is a railroad on each side of the river, the Allegheny Valley Railroad on the east bank, and the West Pennsylvania Railroad on the west bank. The Allegheny Valley Railroad goes as far as Oil City, and the West Pennsylvania Railroad follows the river to a point about a mile and a half above Freeport, where it crosses the river and joins the Pennsylvania Railroad at Blairsville.

The commerce of the river is at present confined to lumber, oil, and stone. There may be a small trade in other materials, but it is so small that it may be disregarded without in the least affecting the present question. Lumber is moved in rafts, oil and stone in flat-boats. The flat-boats used in carrying cobblestones or "bowlders" are called guypers (?). The stone trade is probably the smallest of the three interests. The rafting interest it would be hard to value, as so much lumber goes down the Ohio. The oil interest is probably the most important; not so much in the amount of oil carried by river as in the magnitude of the oil trade proper.

As oil is the only article that is carried in large quantities by other modes than by the river, we must first inquire what the present facilities for carrying it to Pittsburgh are.

The present modes of transportation are three in number: 1st, by rail; 2d, by pipe; 3d, by river; the last being only available during high water. Of the oil carried by rail the greater part is moved by the Allegheny Valley Railroad. Whatever oil is brought by rail from the Butler County region, is taken by the West Pennsylvania Railroad. To the latter road there is a powerful opposition in the Columbia Conduit Company, an organization that has laid a line of pipes from the Butler oil region to a place called Hoboken, about 9 miles above the mouth of the river, and about 1 mile above the city of Pittsburgh, and on the opposite side of the river. At this point the company has four or five tanks, each having a capacity of 8,000 barrels.

While the Columbia Conduit Company was laying its pipes, it desired to carry them across the track of the West Pennsylvania Railroad, but the Pennsylvania Railroad opposed this. The Conduit Company tried to carry its pipes over the road, and then it tried to tunnel under the road, but in each case the Pennsylvania Railroad drove the Conduit Company's men off by an armed force, and finally the matter was carried into the courts and a decision was rendered in favor of the Pennsylvania Railroad. This was unfortunate for the Conduit Company, because its pipe was on one side of the railroad track and its tanks were on the other. The only thing the Conduit Company could do was done. Large tank-wagons were made, and in these the oil was carried from the pipes to the tanks.

When I was last in Pittsburgh, I was told that by some arrangement between the Pennsylvania Railroad and the Baltimore and Ohio Railroad, the former agreed to allow the Columbia Conduit Company to carry the pipe across their track; but whether this agreement will stand in case of a future rupture between the two railroads I cannot say, especially as the Pennsylvania Railroad has the decision of the courts behind it.

Two other pipe-lines are projected, to have a terminus at a point on the Allegheny River about 2,500 feet above the West Pennsylvania Railroad bridge. These lines are owned, the one by the Keystone Pipe Company, the other by the Atlantic Pipe Company. The line of the former was to have been completed by the middle of September. These lines, should the owners desire to extend them to Pittsburgh, will be free from the troubles to which the Columbia Conduit Company was subjected, as they can avoid crossing the track of the West Pennsylvania Railroad.

The cost of bringing oil to Pittsburgh from Parker's Landing is 35 cents per barrel by rail and 12½ to 15 cents by water. This does not include the pipe transportation from the wells to Parker's Landing. The price charged by the Columbia Conduit Company is 30 cents to Hoboken, and 60 cents to refineries situated within the city limits. The cause of this high price to refineries in the city is that the Columbia Conduit Company has an arrangement with the Baltimore and Ohio Railroad by virtue of which the oil, if carried at these rates, must be shipped by that road after having been refined, and the refiners who obtain their oil from the Conduit Company receive a rebate on its arrival at the sea-shore. The Keystone Pipe Company charge 30 cents per barrel for delivering at Freeport, the United Pipe Company 30 cents for delivery at Parker's, and the other lines terminating at Parker's from 20 to 25 cents; but the United Pipe line is considered the best, and buyers seem willing to pay a little more to have their oil delivered by this line.

Boats engaged in carrying oil from Parker's can only run between two and a half to three months during the year, the rest of the time they are idle. They can run on 30 inches of water, or, if not, boats can be built that will do so, and on such a stage of water they could bring to Pittsburgh all the oil the refineries can use, and at half the above rates provided that there were that much water in the Allegheny all the year round. A steamboat with three barges brings on one trip from 4,200 to 5,500 barrels.

The rates given above are for a barrel containing 42 gallons, the trade standard for oil.

We thus see that the cost of transportation from the wells to the heads of the various pipe lines is the same in all cases, viz, 30 cents per barrel.

We also see that the cost of transportation from Parker's Landing to Pittsburgh is by rail 35 cents, and by water 12½ to 15 cents. Hence the cost of a barrel of oil delivered at Pittsburgh is from 20 to 22½ cents less when transported by water from Parker's than it is when transported by rail.

Freeport is nearly half-way between Parker's and Pittsburgh, and, assuming the cost of transportation by rail from Freeport to be two-thirds of the cost from Parker's, we obtain 23⅓ cents; but by water it is 10 cents, making a difference in favor of water-transportation of 13⅓ cents.

The average saving in the cost of transportation per barrel from Freeport or Parker's to Pittsburgh, is 17 cents.

Something over 3 000,000 of barrels of oil are carried yearly to Pittsburgh, and were it all carried by water after it reaches the river, the saving in transportation alone would be $510,000.

In this discussion I have not considered the Columbia Conduit Company beyond merely giving their price of delivery at Hoboken, on account of their peculiar and special arrangements with the Baltimore and Ohio Railroad.

I have also assumed prices by rail from Freeport because I have not yet heard of any oil coming from there in that way.

Whether any of the other pipe-lines will eventually run to Pittsburgh it is impossible to say.

Having seen for how much less oil can be transported by river than by rail, and bearing in mind that the river is available for purposes of navigation but a small time during the year, it is evident that any improvement that would tend to increase the facilities of water-transportation must be of great benefit to the commerce of the river. There is one part of the year when the river cannot be used under any circumstances, and that is during the presence of ice, from about December 1 to April 1, and counting only the period of navigation, we obtain for the saving in transportation $340,000.

It being thus manifest that the oil-trade would be vastly benefited by the existence of permanent navigation, let us see how this permanent navigation can be obtained.

The mode of improvement that naturally first suggests itself is to slackwater the river, but with some departures from the ordinary methods.

This system of improvement has generally been adopted for rivers where the depth of water is almost always too little, but this is not the case on the Allegheny. The pools have at all times plenty of water, and the only obstructions are the ripples to be found here and there, and consequently the improvement to be made confines itself to some means of passing them. The elevations in the bed of the river by which the ripples are formed have steep sides as a rule, consequently a cut of no great length might be made through the ridge, and of such depth as may be determined on. In this cut might be set a lock and the ridge be used as a dam, or a small dam might be constructed on its crest, but in either case the surface of the ridge must be so protected as to make it permanent. The kind of dam to be used, if a dam be adopted, will depend entirely on the site proposed for the structure. As a rule I should prefer movable dams, as causing, when down, less obstruction to the flow of the water, and being covered from shocks from floating bodies, especially ice. The movable dam would undoubtedly be more expensive than the permanent dam, but I think it would be safer under the circumstances. However, the particular improvement to be applied to each case would be a matter of special study.

The next point to examine is how the other two branches of commerce would be affected by such an improvement. All the guyper-men that I spoke to, and they were many, unanimously expressed the hope that the river might be slackwatered and that a good tow-path might be made along the bank. This would doubtless be a great advantage to them, because as the river is now they have very hard work to pass the ripples when being towed by horse power up stream, but to make up for this they can float down. If the river was slackwatered they would have to be towed each way, but still they would prefer this, as they could then make their trips with greater regularity and certainty.

So far as rafting is concerned, it may appear at first sight as though this interest might suffer from the construction of dams, but the experiences of the west branch of the Susquehanna River show that the movements of rafts are in no way interfered with, because the dams on this river are provided with sluices or inclined chutes made for the express purpose of allowing rafts to pass, and at Lock Haven a fall of 11 feet is passed by a sluice or inclined plane, of which the slope is 1 on 142.

The system above proposed seems to me to be the only one that will meet the requirements of the case. If other means be adopted we will have trouble. If we attempt to make cuts through the ridges and have the depth of water sufficient for navigation we run the risk of draining off the upper pool into the lower, and we may also find the cut contemplated to be very long and expensive, and if, on the other hand, we attempt to gain depth by narrowing the channel we will at once produce a velocity of current that will be far too great to stem.

Taking everything into consideration I incline strongly to the system of slackwater by means of movable dams, although a more detailed and elaborate study will be required before anything can be definitely decided on.

It is of course absolutely impossible to predict the exact effect that any improvement of the river may produce, but I think I may safely say that the mere improvement as far as Freeport will be of no advantage except to the Butler County oil trade, because there are many very bad places to be passed between Freeport and Parker's, and the improvement to Freeport will not aid commerce above that point. If any improvement at all be made I opine that it will have to be carried far up the river to be of any value in developing the resources of the country, but whether it would pay to do this is altogether another matter.

I have been informed by gentlemen who have been a great deal in the country adjacent to the upper parts of the Allegheny, that many fine mineral deposits are there; coal, iron-ore, and limestone being found in great abundance and of good quality. The coal deposits could not be made directly available as an article of commerce because it is too soft, and, being apt to break into small pieces by handling, will not bear transportation; but it is an excellent fuel, and can of course be used economically and to great advantage in reducing the surrounding iron-ore and in other local industries. At present there is no coal shipped from the Allegheny Valley, so far as I could learn. I saw one or two abandoned mines, but from what I gathered in conversation with persons familiar with the country I doubt whether any trade of any amount can spring up in this product of the earth. The ore and limestone need some better and cheaper avenue to market than the route by rail, because the prices of transportation are so great now, that it does not pay to bring them to the furnaces near Pittsburgh. Another element must be considered in connection with the development of the coal trade of this region, and that is the natural gas, which is found in apparently inexhaustible quantities, and which they are now beginning to use in connection with the iron manufacture, and I am told that it makes a cheaper and better fuel than coal, and so soon as some means can be found of adapting this gas to this purpose, so as to use it in the best way, I doubt not but that the use of coal will be temporarily, at least, abandoned in this region.

Respectfully submitted,

F. A. MAHAN,
Lieut. Engineers.

Major W. E. MERRILL,
Corps of Engineers.

ANNUAL REPORT

UPON THE

IMPROVEMENT OF THE OHIO, MONONGAHELA, AND WABASH RIVERS,

IN CHARGE OF

W. E. MERRILL,

MAJOR OF ENGINEERS, BVT. COLONEL, U. S. A.;

BEING

APPENDIX P

OF THE

ANNUAL REPORT OF THE CHIEF OF ENGINEERS FOR 1875.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1875.

[EXTRACT FROM THE ANNUAL REPORT OF THE CHIEF OF ENGINEERS TO THE SECRETARY OF WAR.]

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., October 18, 1875.

* * * * * * *

IMPROVEMENT OF THE OHIO, MONONGAHELA, AND WABASH RIVERS.

Officer in charge, Maj. W. E. Merrill, Corps of Engineers, having under his immediate orders Lieut. F. A. Mahan, Corps of Engineers.

1. *Improvement of the Ohio River.*—Of the contracts outstanding at the commencement of the fiscal year, that for the repair of the old dike at French Island has been completed. The first effect of this work was quite satisfactory, but experience has shown that this dike must be extended 1,000 feet farther, so that the sands may be carried into deep water, with the hope that they will there be so distributed as to prevent the re-formation of the bar.

A new contract has been entered into for this extension. The officer in charge considers that this experiment has a very important bearing on the practicability of making a radical improvement of the Lower Ohio by means of dikes.

The dike just above Evansville has been somewhat extended, and its good effect in removing the bar in Evansville Harbor has been increased. It will be still further extended the present season. That the ultimate effect will be to entirely remove this troublesome bar, there can be but little doubt.

The dike at Henderson was nearly finished last season, but extreme low water prevented its entire completion. The total length of this dike is 1,500 feet, but the outer end of the dike for about 200 feet is not yet up to grade.

A dam was built last fall across the chute near the head of Henderson Island, in order to force all the water into the navigable channel. This dam is 40 feet in width and 620 feet long, and is constructed of piles and brush weighted with stone. It has done the work expected of it. Some slight repairs will be needed this season.

The Bacon Rock, at the mouth of the river, has been entirely removed. There is now 6 feet of water on the site of the rock at the lowest stage ever known.

The hull of a new iron snag-boat, under contract with Swift's Iron and Steel Works, was completed on the 1st of March, and contracts for the machinery and joiner-work have since been made, the whole to be completed by November 1, 1875.

The dam at head of Cumberland Island was thoroughly repaired during the year, over 7,000 cubic yards of stone having been placed on it.

Dredging has been carried on in the upper river as follows:

	Cubic yards.
At Brunot's Island	8,499
At Line Island	3,002
At Captina Island	12,011
At the mouth of Muskingum River	3,207
At Buffington Island	59,050

The total number of yards of excavation being 85,769.

Dredging was suspended early in September, on account of the lack of funds. The work of dredging is performed by two dredges belonging to the United States, and cost, during the year 1874, an average of 23 cents per cubic yard.

During the fiscal year there were removed from the channel of the river over 100 snags, 10 wrecks of barges, 6 wrecks of steamboats, (3 wholly and 3 in part,) and 104 large stones.

The officer in charge renews his recommendation for the simultaneous commencement of thirteen locks between Pittsburgh and Wheeling, with a view to making a slack-water improvement by means of movable dams, and estimates the cost of these locks at $2,630,000.

For completing the lock and movable dam, for which the sum of $100,000 was authorized to be expended from the appropriation of March 3, 1875, the sum required for the next fiscal year is	$530,000
And for wing-dams, dredging, and removing snags and bowlders	370,000
Total amount required	$900,000

The site for the movable dam was selected, after careful examination by a board of engineer officers appointed for the purpose, and all of the preliminary steps for the acquisition of the land necessary for its construction were promptly taken; but from the fact that the State of Pennsylvania has not provided for the cession of jurisdiction to lands required by the United States in carrying out its works of improvement, and has no law authorizing the condemnation of lands at reasonable rates for public uses, the land could not be obtained except at exorbitant prices, and the work was of necessity delayed.

It is hoped that the legislature of the State will, at its next session, enact such laws as will enable the United States to proceed without further delay with the prosecution of this important work of improvement.

Balance in Treasury of United States July 1, 1874	$175,000 00
Amount in hands of officer and subject to his check (including $4,525.65 percentage due on contracts not yet completed) July 1, 1874	24,389 49
Amount appropriated by act approved March 3, 1875	300,000 00
Amount expended during the fiscal year ending June 30, 1875	224,778 09
Amount available July 1, 1875, including $8,120.52 due on contracts	274,611 40
Amount required for the fiscal year ending June 30, 1877, including purchase of sites for dams and locks, not exceeding $15,000, (as revised in this Office)	900,000 00

(See Appendix P 1.)

2. *Improvement of the Monongahela River.*—Work on this river consists in building a lock and dam at Hoard's Rocks, West Virginia, ninety-four miles above Pittsburgh and seven miles below Morgantown.

In accordance with the recommendation of the engineer in charge, the time for completion of this lock has been extended from December 1, 1874, to December 1, 1875. Up to the end of the fiscal year the right or land wall of the lock had been completed, excepting a part of the coping.

The quarrying of stone for the dam has been commenced, and will be continued through the season, although, on account of the difficulty of building both lock and dam at the same time, the masonry of the dam will not be begun until low water of next season.

It is expected that the present appropriations will be sufficient to complete the lock and dam, and that the entire work will be ready for use by December, 1876.

The officer in charge recommends the construction of a second lock and dam at Laurel Run, about two miles below the mouth of the Cheat River, at which point a favorable site has been found, with rock foundation, for the lock. The proposed lock will be of the same size as that at Hoard's Rocks, and the same profile will be used for the dam.

The increase in the estimate of cost of this second lock and dam over that at Hoard's Rocks is due to the extra depth of foundation required for the lock, to the greater length of dam, and to inferior conditions for obtaining stone.

No appropriation is asked at present for the dam.

The estimated cost of a stone dam at Laurel Run is $74,000, making the total estimated cost of lock and dam $189,000. The engineer in charge will make an estimate of the cost of a wooden dam at this place, and a comparison of the two methods of construction, in time for the next annual report.

Estimate for fiscal year 1876–'77.

Building lock at Laurel Run	$115,000 00
Balance in Treasury of United States July 1, 1874	103,000 00
Amount in hands of officer and subject to his check (including $403.84 percentage due on contracts not yet completed) July 1, 1874	5,470 73
Amount appropriated by act approved March 3, 1875	22,000 00
Amount expended during the fiscal year ending June 30, 1875	29,184 64
Amount available July 1, 1875, including $3,213.78 due on contracts	101,286 09
Amount required for the fiscal year ending June 30, 1877	115,000 00

3. *Improvement of Wabash River.*—The contract for rock excavation at the Grand Chain, thirty-eight miles from the mouth of the river, was completed in December, 1874, 26,630 cubic yards of excavation having been made. This is the only important work accomplished during the year, as the limited appropriation of 1874 was accompanied by a proviso which forbade its expenditure until the rights and franchises of the Wabash Navigation Company had been extinguished. This was done at a cost of $7,000, but at too late a date to admit of making any new contracts last season.

The following new contracts were made in May, 1875: For closing the cut-off at New Harmony; for rock excavation at Warwick's Ripple; and for clearing out the cut-off at the Little Chain. High water has prevented work under these contracts, except at the Little Chain cut-off, where work was begun on the 3d of June and is now in progress.

The officer in charge again urges an appropriation for building a lock and dam at Grand Rapids, which he considers to be of the greatest importance, and in comparison with which all other improvements should be set aside.

Balance in Treasury of United States July 1, 1874	$40,000 00
Amount in hands of officer and subject to his check (including $2,647.80 percentage due on contracts not yet completed) July 1, 1874	7,984 05
Amount appropriated by act approved March 3, 1875	40,000 00
Amount expended during the fiscal year ending June 30, 1875	38,067 02
Amount available July 1, 1875	49,917 03
Amount required for fiscal year ending June 30, 1877	145,000 00

EXAMINATIONS AND SURVEYS FOR IMPROVEMENT.

To comply with provisions of the river and harbor act of June 23, 1874, Major Merrill was charged with and has completed the following, the results of which were transmitted to Congress at its last session, in reports which were printed in H. R. Ex. Doc. No. 75, parts 8 and 10:

1. *Examination of Little Kanawha River below Bulltown, West Virginia.* (See Appendix P 4.)

2. *Examination of Guyandotte River below Logan Court-House, and of Twelve-pole River below Wayne Court-House, West Virginia.* (See Appendix P 5.)

3. *Survey of Big Sandy River, Kentucky.* (See Appendix P 6.)

And also with surveys for the extension of the *Chesapeake and Ohio Canal from Cumberland to Pittsburgh*, a preliminary report of which was submitted to Congress at its last session, and printed in Senate Ex. Doc. No. 19, part 4. (See also Appendix P 7.)

For completing these surveys a special appropriation of $10,000 was made in the river and harbor act of March 3, 1875. They are now progressing satisfactorily.

* * * * * * *

REPORT.

APPENDIX P.

ANNUAL REPORT OF MAJOR WM. E. MERRILL, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1875.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, July 16, 1875.

GENERAL: I have the honor herewith to transmit annual reports on the works under my charge for the fiscal year ending June 30, 1875.

Very respectfully, your obedient servant,

WM. E. MERRILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

P 1.

IMPROVEMENT OF THE OHIO RIVER.

At the beginning of the fiscal year the following contracts were outstanding:

Number.	Miles below Pittsburgh.	Work.	Contractors.
1	760	French Island Dike	C. M. Cole.
2	783	Dike at Evansville, Indiana	J. S. Routh.
3	797	Henderson Island Dike	Do.
4	797	Henderson Island Dam	Do.
5	967	Removal of Bacon Rock	M. A. Bryson, (surety.)
6	.....	Hull of iron snag-boat	Swift's Iron and Steel Works.

French Island Dike, 760 miles below Pittsburgh.—In my last annual report, dated September 1, 1874, I stated that since June 30, 1874, this dike had been completed. The quantities of material mentioned in that report were those expended prior to the end of the last fiscal year. During the fiscal year just closed there were expended 5,366 cubic yards of stone, and 4,228 cords of brush, making a total expenditure of 7,181 cubic yards of stone, 9,637 cords of brush, and 705 piles, in building a dike 2,000 feet in length on a shifting sand-bar of the Lower Ohio. It should be stated that the amount of material given above includes that expended in protecting the shore for a distance of 300 feet below the root of the dike. Besides building this dike, about 1,000 yards of stone were placed on the dike at the foot of the island.

The first effect of this dike was excellent; river-men were delighted with it, and I thought that a radical improvement had been made. Unfortunately I discovered, after my report had gone in, that although good water was made and maintained where the bar was when I commenced work, yet the sands had reformed a bar just below the end of the dike, so that very little practical advantage had resulted from the work. Accordingly, with the approval of the Chief of Engineers, I have made a new contract (details of which will be given further on) for an addition of 1,000 feet to the length of the dike. I hope that this extension will drive the sands into deeper water, and cause them so to distribute themselves along the sides of the channel as to leave good navigable water in the middle. I consider this experiment a very valuable one in determining the utility of attempting the radical improvement of the Lower Ohio, by using dikes to guide and control the currents. If the result is to be a mere shifting of a bar from one place to another, a servicable improvement will require a continuous line of submersible dikes throughout the whole length of the river, and this would be both costly and annoying to navigation. Before this report reaches Congress I expect to have the extension completed, but two or three seasons' experience will be needed to determine the full value of the experiment.

Department letter of April 28, 1875, directs me to report what has been the gain in depth in the Ohio River under the plans heretofore adopted for its improvement.

In reply, I would state that no definite answer can be given. The nature of the bottom varies so much in different parts of the river, and the amount of traveling sand is so various, that the available depth on all bars, improved or unimproved, is always uncertain. The effect of the contraction also varies at different stages of water. Thus at the Trap, near Pittsburgh, the depth in dead low water, when the total amount of water passing is very small, is probably not increased more than 2 or 3 inches. At a higher stage the dike prevents the water from spreading, and thus secures a greater navigable depth than if it were not there. Some places, like Glass-house, at Allegheny City, have been radically improved, but the radical improvement consists in having such a depth that boats can always pass when they can pass the Trap. Formerly the Glass-house bar was the worst of the two.

At Medoc, Warsaw, and Rising Sun there has been an appreciable gain for ordinary stages, but in dead low water the gain almost disappears, because at such stages the flowing volume is so small, that it would naturally contract into a channel of about the same width as that caused by the dike, and therefore at such stages the dike can have but little effect. As a rule, I think that the effect of dikes and dams is more in preventing water from spreading during stages of from 2 to 6 feet above low water than in any increase in depth at dead low water. The worst places of course control navigation, and I should say that between Pittsburgh and Wheeling we cannot depend, after improvement, upon more than 18 inches in ordinary low water; between Wheeling and Huntington, on more than 2 feet; between Huntington and Portsmouth, on more than 2½ feet; between Portsmouth and Louisville, on more than 3 feet; and, below Louisville, on more than 3½ feet. The sands are very troublesome from Portsmouth down, but especially so below the falls. Whether we can permanently control them by open-river improvement, can be told with some certainty after we see the results of extending the dike at French Island.

Evansville Dike, 783 *miles below Pittsburgh*.—I have not pushed this work, believing it better policy to extend the dike slowly, so as to give the river time to gradually work out its new channel along the river front at Evansville. The reports that I receive from time to time are all favorable, the bar being now greatly reduced from its former size. The greatest wash of the bar always takes place during high water. The floods of last winter undoubtedly had a good effect, but the river is still too high to permit, at this writing, a report in detail of what that effect has been. Mr. C. B. Bateman, the engineer in charge, writes as follows, under date of June 26, 1875:

> From observation so far made about the dike at Evansville, there appears to have been a considerable scour across the bar above the water-works, coming down the old pocket; and where the highest point of sand went out of sight last season at 6.40 feet, [on the gauge,] there is now 2 feet of water below, or at that stage. The steamboat-channel, however, continues outside the bar.

During the last fiscal year 3,814 cubic yards of stone, 7,391 cords of brush, and 321 piles were placed in the dike, making a total thus far used of 7,858 cubic yards stone, 13,355 cords of brush, and 684 piles. The dike is 1,525 feet in length and 50 feet in width. The dike will be further extended during the present season.

Henderson Dike, 797 *miles below Pittsburgh*.—The dike was nearly finished last season, but the necessity of rapidly building the dam and the obstruction to work of all kinds, caused by the extreme low water, made it impracticable to complete operations. During the last fiscal year 3,102 cubic yards of stone, 3,929 cords of brush, and 234 piles were placed in the work, making a total of 5,523 cubic yards of stone, 9,100 cords of brush, and 616 piles. The total length of the dike is 1,500 feet, but the outer end of it for a distance of 200 feet has not yet been raised to grade.

Henderson Dam, 797 *miles below Pittsburgh*.—The necessity for this dam was set forth in my last annual report. It was built across the chute, and as near the head of the island as practicable. The bank was carefully protected by piles, brush, and stone extending from 100 feet above the dam to 200 feet below it before work on the dam was begun. The dam is 40 feet in width, with three rows of piles 6 feet apart, the space between the upper rows being 15 feet, and between the middle and lower rows 25 feet. The spaces between the rows are filled with loose brush and stone. The total length of the dam is 620 feet. There were used in its construction 3,872 cubic yards of stone, 6,585 cords of brush, and 414 piles. A recent inspection shows that some repairs will be needed during the present season.

Bacon Rock, 967 *miles below Pittsburgh*.—This rock has been entirely removed in the manner detailed in my last report. The dredge employed was of the clam-shell type, and found no difficulty in lifting the loosely-cemented gravel and sand that formed the inside of the rock. The cementing substance was mainly iron. The gravel was identical with that used in Paducah for road-metal, for which it is particularly valuable. The *débris* of this lately-formidable obstruction were placed on the Cairo levee.

Iron hull for snag-boat.—The contract with Swift's Iron and Steel Works for the construction of the hull of this boat was completed on the 1st of March, on which date the hull was floated by a rise in the river. The workmanship was very satisfactory, and the hull reflects great credit upon its builders and its designers. This work was placed under the special charge of Mr. William Weston, my principal civil assistant, and Mr. G. S. Kinsey, mechanical engineer. Major Suter, Corps of Engineers, gave us the full benefit of his experience throughout the work. Mr. W. H. Christian was the inspector in charge on the part of the United States. Whatever credit is due to the successful construction of this intricate boat belongs to the persons named. The hull when launched drew 21 inches at the stem and 15 inches at the stern-post. It is expected that the finished boat will draw 28 inches. This will be an immense advantage over the wooden-hull snag-boats, which draw 4½ feet.

Cumberland Dam, 907 *miles below Pittsburgh.*—After the river had fallen sufficiently to bring to view the top of the Cumberland Dam, it was found that a large portion of the old part of the dam, which was supposed to be strong and therefore left untouched, had sunk below grade, and that a gap had been opened at the junction between the new and the old work. By authority of the Chief of Engineers, a contract for the repair of these injuries was let to Messrs. Miller & Bedard, the old contractors, who again proved the lowest bidders. They used 7,185 cubic yards of stone, and put the dam in good condition. Its present state is unknown, as it has been out of sight since the repairs were completed.

The following new contracts were made in June, 1875:

Number.	Miles below Pittsburgh.	Work.	Contractor.
1	760	Extension of French Island Dike	C. M. Cole.
2		Machinery of snag-boat	A. Hartupee.
3		Joiner-work and painting of snag-boat	W. F. Richardson.

French Island Dike, 760 *miles below Pittsburgh.*—A contract for adding 1,000 feet to the length of this dike was made on the 18th of June, 1875. The reasons for this work are set forth in the first part of this report. Work on the extension has not yet been begun.

Iron-hull snag-boat.—The contracts for completing the new Ohio River snag-boat E. A. Woodruff were let to A. Hartupee and W. F. Richardson, of Pittsburgh, on the 5th of June, 1875. These contracts require that the boat shall be finished by November 1, 1875, and according to present appearance this condition will be fulfilled.

DREDGING.

Work has been vigorously prosecuted during the past year by the United States dredges Ohio and Oswego, except that I was compelled, for lack of funds, to suspend operations on the 10th of September, 1874. This suspension, at a time when there were three good working-months ahead, was very unfortunate. By cutting short the available working-season the average cost per cubic yard of excavation was made much greater than it otherwise would have been.

During the fiscal year dredging was accomplished as follows:

	Cubic yards.
Bar at foot of Brunot Island	8,499
Lump at head of Line Island Chute	3,002
Bar at Captina Island	12,011
Bar at mouth of Muskingum	3,207
Bar at Buffington Island	59,050
	85,769

In addition the following obstructions were removed from the channel by the dredges:

Coal-boat below Wellsburg, W. Va.
Barge above Pike Island.
Two snags near Pike Island.
Wreck below Marietta Island.
Three snags below Marietta Island.

The dredges were not designed for wrecking, but as they move up and down the river they are expected to remove whatever they can that is seriously in the way.

The following tables show the cost of the work done by the dredges during the year 1874. They are based upon the operations of the calendar, and not of the fiscal year, because the former coincides with the working-season:

Number.	Dredge Ohio, 1874.	Miles from Pittsburgh.	Dredge in commission.													
				Days lost.				Salaries.			Equipment.			Repairs.		
			Days of work.	Traveling.	Repairing.	High and low water.	Days in commission.	Per day.	Per day of work.	Total.	Per day.	Per day of work.	Total.	Per day.	Per day of work.	Total.
1	Brunot's Island, dredging	4	55. 0	3. 0	23. 5	4	85. 5	$26 35	$40 97	$2, 258 05	$1 75	$2 70	$149 62	$4 65	$7 25	$397 57
2	Line Island, dredging	41	5. 0	0. 5	2. 1		7. 6			200 73			13 30			35 19
3	Line Island, rocks and snags	41	1. 0	0. 5	0. 4		1. 9			50 18			3 32			8 84
4	Wellsburg, wreck and snags	74	1. 0	0. 5	0 4		1. 9			50 18			3 32			8 84
5	Pike Island, wreck and snags	83	1. 5	0. 5	0. 6		2. 6			68 68			4 55			12 09
6	Captina, dredging	109	17. 0	0. 5	7. 5	2	27. 0			713 07			47 25			125 55
7	Captina, snags	109	0. 5	0. 0	0. 2		0. 7			18 50			1 22			3 25
8	Fish Creek, snags and wreck	113	1. 5	0. 5	0. 6		2. 6			68 68			4 55			12 09
9	Marietta, dredging	171	7. 0	1. 0	2. 5		10. 5			277 32			18 38			48 83
10	Big Hocking, snag	198	0. 5	0. 5	0. 2		1. 2			31 80			1 10			5 58
11	Buffington, dredging	215	12. 0	0. 5	5. 0		17. 5			462 18			30 63			81 37
	Total		102. 0	8. 0	43. 0	6	159. 0	26 35	40 97	4, 199 50	1 75	2 70	277 24	4 65	7 25	739 20
	DREDGE OSWEGO, 1874.															
1	Brunot's Island, dredging	4	49. 0	3. 0	29. 5	4	85. 5	26 35	40 97	2, 258 05	52	1 07	44 20	6 15	12 71	526 35
2	Line Island, dredging	41	5. 0	0. 5	2. 1		7. 6			200 73			3 93			46 78
3	Line Island, rocks and snags	41	1. 0	0. 5	0. 4		1. 9			50 18			98			11 69
4	Wellsburg, wrecks and snags	74	1. 0	0. 5	0. 4		1. 9			50 18			98			11 69
5	Pike Island, wrecks and snags	83	1. 5	0. 5	0. 6		2. 6			68 68			1 34			16 00
6	Captina, dredging	109	9. 0	0. 5	15. 5	2	27. 0			713 07			13 96			166 24
7	Captina, snags	109	0. 5	0. 0	0. 2		0. 7			18 50			36			4 31
8	Fish Creek, snags and wreck	113	0. 5	0. 5	1. 6		2. 6			68 68			1 34			16 00
9	Marietta, dredging	171	4. 0	1. 0	5. 5		10. 5			277 32			5 43			64 63
10	Big Hocking, snag	198	0. 5	0. 5	0. 2		1. 2			31 80			62			7 39
11	Buffington, dredging	215	14. 0	0. 5	3. 0		17. 5			462 18			9 05			107 63
	Total		86. 0	8. 0	59. 0	6	159. 0	26 35	40 97	4, 199 37	52	1. 07	82 19	6 15	12 71	978 71

Number.	Dredge Ohio, 1874.	Dredge in commission.			Out of commission.			Excavation.			Cost.					
		Towing.														
		Per day.	Per day of work.	Total.	Days laid up.	Cost per day laid up.	Total.	Total cubic yards.	Average cubic yards per day.	Average cubic yards per day of work.	Per cubic yards of excavation.	Per day.	Per day of work.	Total wrecking.	Total dredging.	Total expense.
1	Brunot's Island, dredging	$27 31	$42 57	$2, 335 00	82.5	$3 07	$253 27	24, 902. 0	291. 2	442. 9	$0. 205	$60 12	$87 23		$5, 140 52	$5, 140 52
2	Line Island, dredging			207 56	7.5		23 03	2, 173. 0	280. 5	434. 6	0. 213				456 94	456 94
3	Line Island, rocks and snags			51 89	1.5		4 61							$114 24		114 24
4	Wellsburg, wreck and snags			51 89	1.5		4 61							114 24		114 24
5	Pike Island, wreck and snags			71 00	2. 06		6 33							156 32		156 32
6	Captina, dredging			737 37	25. 5		78 29	6, 318. 0	234. 0	371. 5	0. 256				1, 623 32	1, 623 32
7	Captina, snags			19 12	0. 7		1 72							42 09		42 09
8	Fish Creek, snags and wreck			71 00	1. 6		5 46							156 32		156 32
9	Marietta, dredging			286 76	10. 5		32 24	4, 587. 0	437. 5	655. 3	0. 137				631 29	631 29
10	Big Hocking, snags			32 77	0. 56		1 72							72 15		72 15
11	Buffington, dredging			477 93	18. 0		55 26	4, 359. 0	243. 4	363. 3	0. 240				1, 052 16	1, 052 16
	Total	27 31	42 57	4, 342 29	153. 0	3. 07	466 24	42. 339. 0	266. 3	415. 0	0. 212	60 12	87 23	655 36	8, 904 23	9, 559 59
	DREDGE OSWEGO, 1874.															
1	Brunot's Island, dredging	27 31	42 57	2, 335 00	84. 5	3 07	253 27	23, 961	280. 2	489. 0	0. 215	60 26	124 43		5, 151 00	5, 151 00
2	Line Island, dredging			207 56	7. 5		23 03	2, 667	351. 0	533. 4	0. 172				459 83	459 83
3	Line Island, rocks and snags			51 89	1. 5		4 61							114 49		114 49
4	Wellsburg, wrecks and snags			51 89	1. 5		4 61							114 49		114 49
5	Pike Island, wrecks and snags			71 00	2. 14		6 33							156 68		156 68
6	Captina, dredging			737 37	25. 5		78 29	4, 813	178. 2	534. 8	0. 348				1, 620 46	1, 626 46
7	Captina, snags			19 12	0. 7		1 72							42 18		42 18
8	Fish Creek, snags and wreck			71 00	1. 6		5 16							156 67		156 67
9	Marietta, dredging			286 76	10. 5		32 24	1, 237	117. 8	309. 2	0. 511				632 73	632 73
10	Big Hocking, snags			32 77	0. 56		1 72							72 31		72 31
11	Buffington, dredging			477 93	18. 0		55 26	5, 872	335. 6	419. 4	0. 179				1, 054 36	1, 054 36
	Total	27 31	42 57	4, 342 29	154. 0	3 07	466 24	38, 550	242. 5	448. 2	0. 248	60 26	124 43	666 82	8, 924 38	9, 581 20

EXPLANATORY NOTES.—Under repairs are included expenditures for additional fixtures that were found to be necessary for successful work.

Repairing done in the spring, before commencing work, has been distributed proportionally on all the work.

The amounts spent for equipment were for tools, rope, oil, cotton-waste, &c.

The cost of the dredges while "laid up" is included in salaries and equipment.

The contract price for towing was $55 per day, Sundays excepted, and the boat was paid for all working days while under charter. One tow-boat tended both dredges, which worked together at all times. Under the charter coal for the dredges was furnished by the tow-boat without additional charge.

In order to get the total cost of work, the cost of the dredges while laid up, as shown under the heading "Out of Commission," has been proportioned among the places where work was done. The crews of the dredges subsisted themselves.

It will be observed that the average cost to the United States per cubic yard dredged was but 25 and 21 cents, notwithstanding the limited time during which the dredges worked. This cost includes repairs, new equipment, and expenditures of all kinds on the dredges, but does not include interest on investment or depreciation of plant. Before these dredges were built the contract price on the Ohio was from 80 cents to $1 per cubic yard. Each season's work demonstrates more clearly the advantage to the river improvement of owning the dredges.

It should be borne in mind that dredging in a shallow and swift river like the Ohio is both more difficult and more costly than similar work in deep and comparatively quiet waters.

REMOVING WRECKS AND OBSTRUCTIONS.

The following wrecks, snags, and rocks were removed by hired labor during the last fiscal year, besides those just mentioned as removed by the dredges:

Eighty-four rocks and several snags between Marietta and Buffington Island.
Three coal-barge wrecks at Buffington Island.
Twenty-six snags and 19 large rocks between Buffington Island and Turkey Creek bar.
Coal-boat at Raccoon Island.
Twenty-five snags and one rock between Raccoon Island and Sheridan's coal-works.
Thirty-seven snags between Cincinnati and Madison, Ind.
Several snags opposite Lawrenceburg.
Stone-boat at Rising Sun.
Log at Craig's bar.
Wreck of Alleghany Belle near Portland, Ky.
Wreck of model-barge near Portland, Ky.
"Anna" log at Diamond Island.
Log opposite Paducah, Ky.

The wrecking party which was employed during the preceding fiscal year on the wreck of the "Missouri" above Evansville was re-employed during the year just closed, and removed the following wrecks:

Remains of wreck of Missouri.
Wreck of "Fulton."
Part of wreck of "Queen of the West."
Wreck of coal-barge lying near Fulton.
Wreck of "Umpire."
Part of wreck of "Jenny Howell."

SPECIAL SURVEYS.

During the year the following special surveys have been made:

Harbor of Pittsburgh.
Sites for thirteen locks and dams between Pittsburgh and Wheeling.
Land required for the movable dam at Davis's Island.
Observations of coal-fleets passing site of Cincinnati Southern Railroad bridge.
Little Chain.
Upper part of Grand Chain.

OFFICE-WORK.

Office-work during the year has comprised the preparation of a continuous map of the river on a scale of 2 inches to the mile, of detailed drawings of upper works and machinery of the snag-boat E. A. Woodruff, of hydrographs of Ohio River gauge records, of drawings of lock-gates and wickets of a movable dam, of drawings and tracings of special surveys, and miscellaneous works of various kinds. A model of a Chanoine movable dam, comprising ten wickets, on the scale of one inch to the foot, has also been made.

ESTIMATE FOR 1876–'77.

The question of the proper method of improving the Upper Ohio, at least between Pittsburgh and Wheeling, was submitted to a Board of Engineers which met at Pittsburgh on the 14th of April, 1875, and reported in favor of the plan which was recommended in my last annual report.

The appropriation act of March 3, 1875, reads as follows:

> For the improvement of the Ohio River, three hundred thousand dollars; that one hundred thousand dollars of this amount shall be used for and applied toward the construction of a "movable dam," or a dam with adjustable gates, for the purpose of testing substantially the best method of improving permanently the navigation of the Ohio River and its tributaries; the location of this work, with the plan of construction, and the application of the amount hereby appropriated, to be submitted to the Secretary of War, for his approval.

In accordance with the terms of this act, the report of the Board was submitted to the Secretary of War, was approved by him, and I was ordered to prepare for active operations. Before commencing, it was necessary to purchase sufficient land for the lock and its approaches, for the abutment on Davis's Island, and for the two abutments of the permanent dam behind Davis's Island. The laws of the United States require that before the construction of any Government work, the State in which it is located shall cede to the United States its jurisdiction over the land so purchased. Knowing this, and anticipating the improvement of the Ohio by locks and dams, in 1873 I drew up the project of a bill for cession of jurisdiction by the State of Pennsylvania over all land that might be needed in Pennsylvania for the improvement of the Ohio River by locks and dams, and forwarded it to General Moorhead, of Pittsburgh, the chairman of the Ohio River Commissioners. General Moorhead revised and modified the proposed bill, and then caused it to be introduced into the Pennsylvania legislature in the session of 1873–'74. The bill passed both houses, but was vetoed by the governor. During the session of 1874–'75, a new bill was introduced, drawn up so as to obviate the governor's objections, and this bill passed the lower house, and was sent to the senate. Unfortunately the bill was mislaid, and could not be found when called in its order. The legislature adjourned without acting on it, but the bill came up again at the next session as unfinished business. The non-passage of the bill, together with the enormous prices set on their property by the riparian owners, caused you to order me to postpone all operations on the dam until the bill was passed. It contained a clause giving the same right of condemnation usually granted to railroads, and when it does pass we will be able to get the necessary land at a fair price. This state of affairs is very annoying, but I feel that I did all that I could to guard against it, and that it did not occur through any neglect or carelessness on my part.

In my last year's estimate I recommended the simultaneous construction of thirteen locks between Pittsburgh and Wheeling, rather than to commence on a smaller number of complete movable dams with locks. My reason for this recommendation was that all the locks could be under way at the same time without interfering with each other, or with navigation. After these were built all the dams could be undertaken simultaneously, and as it would take no longer to build thirteen independent dams than one, the navigation of the river would only be obstructed for two years, while a different policy would obstruct it during every year until the whole work was completed. I therefore can do no better than to repeat my former estimate, which is as follows:

Thirteen locks, at $200,000	$2,600,000 00
Engineering and contingencies of locks—5 per cent	130,000 00
Nine months' services of dredges	27,000 00
Nine months' service of snag-boat	27,000 00
Improvement of Lower Ohio	180,000 00
Office expenses, inspector, stationery, quarters, and traveling	22,000 00
Contingencies	14,000 00
	3,000,000 00

The estimates on the thirteen locks are only approximate, because last year's operations did not suffice to determine absolutely the location for all the locks, and since then the stage in the river has been higher than it should be for first-class work. Between now and December the necessary re-examinations will be made, and reasonably accurate estimates may be prepared. The average cost of a lock will be greater than $200,000, as many of them must be built on gravel, but as I cannot yet make exact estimates I prefer to let the first approximate estimate remain.

In my report (Ex. Doc. 19, part 8, Senate, Forty-third Congress, second session) on the radical improvement of the Ohio, I estimated the cost of a lock as follows:

On rock foundation	$179,610 00
On gravel foundation	285,168 00
Average	232,389 00

The bars that need improvement on the Ohio below the Falls are the same that were mentioned last year—namely, Portland, Flint Island, Puppy Creek, Scuffletown, Three-mile Island, Shawneetown, Treadwater, foot of Cumberland Island, and The Grand Chain. At the latter place the Jackson Rock should be removed, even if nothing else is done. The estimate of $180,000 is not sufficient to do all this work, but no reliable estimates can be made, and the places where work should be done must be determined by the condition of the river during the preceding low water.

As this estimate is made in July, 1875, for work which is not to be commenced before July, 1876, and as it is made while the river is high, and in advance of the work of the present season, it is necessarily vague. As an illustration of the difficulty of predicting work so far ahead, I will only state that during this year I will be unable to work at any of the bars mentioned above, but instead I have been obliged to let a contract for additional work at French Island, a bar that I considered as radically improved when my last annual report was written.

Financial statement.

Balance in Treasury of United States, July 1, 1874	$175,000 00
Amount in hands of officer and subject to his check (including $4,525.65 percentage due on contracts not yet completed) July 1, 1874	24,389 49
Amount appropriated by act approved March 3, 1875	300,000 00
Amount expended during the fiscal year ending June 30, 1875	224,778 09
Amount available July 1, 1875, including $8,120.52 due on contracts	274,611 40
Amount required for the fiscal year ending June 30, 1877	3,000,000 00

Supplement to report of Board of Engineer officers submitted January 31, 1874.

NOVEMBER 24, 1874.

GENERAL: The Board of Engineers on movable dams and hydraulic gates, as applicable to the improvement of the Ohio River, who submitted a report on this subject on the 31st of January last, which was printed as Ex. Doc.* No. 127, House of Representatives, Forty-third Congress, first session, would respectfully forward herewith two additional translations from recent numbers of the *Annales des Ponts et Chaussées*, which they believe will prove useful and interesting in that connection. One of them describes the dam at Port-à-l'Anglais on the Seine, and the other gives the details of the Girard shutters used on the weir of the Île Brûlée dam across the Yonne. The Board are greatly indebted to Lieut. F. A. Mahan, engineers, for valuable assistance in making these translations.

Three plates accompany the text; they have been numbered consecutively with the plates of the former report.

Respectfully, your obedient servant,

G. WEITZEL,
Major of Engineers & Bvt. Maj. Gen., U. S. A.
WM. E. MERRILL,
Major Engineers & Bvt. Col.

Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

NEW NAVIGABLE PASS ESTABLISHED IN 1870 IN THE PORT-À-L'ANGLAIS DAM.

MOVABLE WICKETS SUSTAINING A LIFT OF THIRTEEN FEET.

Description by M. Boulé, Engineer of Ponts et Chaussées.

CHAPTER I.

BRIEF DESCRIPTION OF THE PORT-À-L'ANGLAIS DAM.

[NOTE.—All dimensions and calculations have been adapted to the use of English measures.]

The Port-à-l'Anglais dam, which is situated on the Seine, two and a half miles above Paris, and whose general plan and cross-sections are shown by plates 18 and 19, is composed of the following works:

LOCK.

The lock located on the left bank of the river has a total length of 689 feet, and available length 590 feet, and a width of 39 feet; built between 1861 and 1863, with two masonry ends, including between them a lock-chamber with earthen walls, whose slopes, inclined at 45°, were revetted with dry stone; it was made 3 feet 3 inches deeper in 1869. At the same time the sloping revetments were replaced by vertical stone walls, 52½ feet apart. This width of 52½ feet is the same that was afforded by the old chamber when the lower level was at its usual height; it is a necessity, in order that the lock may contain two lines of boats, 25½ feet wide, (boats that ply on the Saint-Martin Canal.) The floor of the lock-chamber, whose natural surface has received no revetment or covering, is now lowered, as is also the lower miter-sill, to the reference 79.60 of the general leveling of France [in feet above the sea-level;] that is, to 8½ feet below the low water of 1840, which reads zero on the water-gauge at the La Tournelle bridge. The normal lift of the Suresnes dam being fixed at the reference 85.40, and the slope from Port-à-l'Anglais to Suresnes being not less than 9 inches, the draught of water on the lower miter-sill of the Port-à l'Anglais lock can only exceptionally descend below 6½ feet. The upper miter-sill has not been changed; it is at the reference 80.87, with a lift-wall 3 feet 3 inches in height.

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* See Annual Report of the Chief of Engineers, 1874, Appendix N 3.

DAM.

The dam proper (the old navigable pass) has an opening of 179½ feet between the exterior face of the lower end of the lock and that of the first pier; its sill is at the reference 86.15; that is, it is 6½ feet higher than the lower miter-sill of the lock. It has forty-two wickets, 9 feet 10 inches high, and 3 feet 11 inches wide, with intervals of 4 inches. It is closed by means of a maneuvering boat, and it is opened by tripping-rods. No change has been made in this part of the work since it was built in 1863, by MM. Chanoine and De Lagrené; it therefore conforms to the type of navigable passes described in the articles written by these engineers. (Annales, 1861, 1868.)

WEIR.

The weir built in 1864, according to M. Chanoine's system, of automatic wickets, provides, between the pier and the abutment on the right bank, an opening of 230 feet; it was closed by fifty wickets 6 feet 7 inches high and 4 feet 3 inches wide; its sill is, at the reference, 89.76. A breach of about 115 feet was made in it in 1869, near the right bank, in order to provide a temporary channel for navigation during the continuance of the work undertaken on the lock. Its length is at present reduced to 124¼ feet, and it now has only twenty-seven of the former wickets. A service foot-bridge, supported by twenty-seven movable trestles, like those of the Poirée dams, on which rolls a lifting windlass, was constructed above the wickets in 1870.

All the maneuvers of the wickets are now readily performed by means of this windlass, and the apparatus of movable counter-weights, with which they were originally provided, has been removed, having become useless after the construction of the foot-bridge. (See, on this subject, the additional note at the end of this article.)

SLUICE.

The sluice which is the object of this article was constructed between the 1st of May and 23d of October, 1870, in order to close the breach opened in the weir in 1869.

When the wickets are down it gives an opening of 94¼ feet between the pier which separates it from the weir and the abutment on the right bank, whose alignment has been preserved. Its sill has been fixed at the reference 83.86; that is, at 2 feet 4 inches below that of the old navigable pass. The level of the lower pool usually does not fall, during low water, below the reference 86.15, as has been mentioned above; the draught of water on the sill of the sluice will therefore be, except occasionally, greater than 2 feet 4 inches. On the other hand, the lowest water known at Port à-l'Anglais was observed on September 29, 1865, to be at the reference 84.64, and on July 27, 1870, at the reference 84.87; but these extraordinary depressions each time only lasted a few hours. The first time the Suresnes dam had not been built; the second time it was completely open, and in the two cases the discharge of the Seine was exceptionally reduced by the simultaneous closing of several of the dams situated above Paris, and the lock, whose four gates were open, then sufficed for the total discharge of the Seine.

The normal back-water of the Port-à-l'Anglais dam rises to the reference 96.00; that is, to 12 feet 2 inches above the sill of the sluice; but the strength of all the parts of the latter construction has been calculated on the supposition that a sheet of water 1 foot 4 inches in depth may flow over the tops of the wickets, or, what is nearly the same thing, on the supposition that the height of the wood-work of the new wickets may subsequently be increased so as to give 6 feet 7 inches of draught in the upper pool instead of 5 feet 3 inches.

This work has, then, been built so as to be able to maintain a lift of 13 feet 5 inches above its sill. In fact, since it has been in operation the lift has several times been increased to nearly this height. Thus, on November 23, 1871, and on January 20, May 22, and October 14, 1872, the water-surface was raised, without the least inconvenience, as much as 13 feet 1 inch and 13 feet 3 inches above the sill.

The difference of level is as much as 9 feet 10 inches, and may be even greater when the water is low in the lower pool. Thus, on October 3, 1872, the water above the dam rose to the reference 96.45, and below it to the reference 86.71. It has been shown above that this last level could fall to 86.15, and even lower.

The movable apparatus for closing the new sluice was constructed according to the system of M. Chanoine, but in order to support so great a pressure of water it appeared necessary to modify some parts of the models designed and executed by M. Chanoine for wickets of 9 feet 10 inches in height. This remarkable system, the only one which experience has thus far sanctioned for movable dams of great height and considerable difference of level, being well known, it will suffice to describe these modifications. They are five in number, and relate to the width of the wickets; the height of their axis of rotation; their inclination to the vertical; the traverse profile of the floor; and, lastly, the substitution of a service foot-bridge for the maneuvering boat.

CHAPTER II.

PRINCIPAL ARRANGEMENTS OF THE WICKETS OF THE PASS.—DIMENSIONS OF THE WICKETS.

Chanoine wickets, 9 feet 10 inches in height, are 3 feet 11 inches wide, and the static pressure of the water on the up-stream face of each one of these does not exceed from 13,000 to 15,000 pounds. It will be seen further on that the same pressure may exceed 6,047 pounds per running foot for the tall wickets of Port-à l'Anglais. It was then very desirable to reduce as much as possible the width of the latter. It has been fixed at 3 feet 3 inches, and it would hardly have been possible to adopt a less width without reducing beyond measure the width of the horses, whose base ought to be large enough to insure stability in a plane at right angles to the axis of the river, and to prevent the wickets from bending to the right or the left of their normal position under the action of the oblique forces which they may sometimes have to sustain either when upright, or when dropped on the floor.

Reduced to a width of 3 feet 3 inches, the wood-work of the wickets has been simplified by suppressing two out of the four uprights. Figures 101 and 104, Plate 19, show the arrangements adopted. A wicket is simply composed of two 8 by 12 stiles, 12 feet 8 inches long, connected by four transoms, with mortises and tenons, and with two 2-inch planks fastened to these transom-pieces between the stiles. The upper transom, that belonging to the chase, is strengthened by an iron band, as is also the transom belonging to the breech, and, in addition, large bolts, 3 feet 3 inches long, traverse the entire width of the wood-work, and give it great stiffness by binding the stiles against the transoms and the planking.

The cast-iron counterweight placed on the breech is held by a bolt which passes through it; it weighs about 220 pounds.

WASTE OF WATER THROUGH THE DAM.

As it is important to reduce as much as possible the volume of water which can flow through the dam when the difference of level is great, the wickets have been made water-tight by tonguing and grooving the two planks and by supporting them on rabbets cut in the stiles, while in the wickets first made much water was wasted through the seven vertical cracks between the four uprights and the four planks, which only touched each other.

Nevertheless, the interval of four inches has been preserved between two neighboring wickets, as it appeared necessary in order to prevent them from striking one another during the maneuvers, when they are slightly thrown out of their normal position by an oblique traction. Moreover, this space is useful to provide for the discharge at mean stages; and if it should prove too wide during low water, it can easily be reduced by nailing small battens of from three-quarters of an inch to an inch and a quarter on the side of a stile.

If we call Q the height of the lower pool above the sill, and H the difference of level, we can calculate approximately the discharge through the interval of four inches between the two wickets by the formula for the discharge over a weir:

$$Q = 0.33\ (0.60\ h + 0.40\ H)\ \sqrt{2\,g\,H}$$

If we suppose the lower pool at the reference 86.15, and the upper at the reference 96.00, this formula gives, for the Port-à-l'Anglais sluice, $Q = 43.334$ cubic feet; for the old navigable pass, $Q = 32.492$ cubic feet, and for the river, $Q = 17.658$ cubic feet.

Therefore for the whole dam—

$$28 \times 17.658 + 43 \times 32.492 + 27 \times 43.334 = 3061.60 \text{ cubic feet.}$$

This discharge is nearly double that of the lowest water in the Seine; but experience has proved that it can be reduced almost as much as may be desired by making the interval between the wickets by joint-covers or wooden needles, which the lock-tender easily manages while passing along above the dam in a boat. Thus far the placing of joint-covers over half, or at most over three-fourths, of the spaces between the wickets has sufficed to keep up the level of the Port-à-l'Anglais pool.

The joint-covers which seem to have succeeded best for the sluice are needles with square cross-sections; they are placed as wedges between two adjoining wickets, the faces of the needles making an angle of 45° with those of the wicket. For the old pass, as for the other dams of the Upper Seine, whose lift is much less, joint-covers are used of from nine and a half to twelve inches in width and two inches in thickness, and they are laid flat on the up-stream faces of the wickets; but the square needles, placed as wedges, cause a greater diminution of the discharge. It is quite probable that the dam can be made almost completely water-tight by needles of a suitable shape, covered with leather or India rubber, if it should become necessary to reduce the loss of water to the minimum, for instance, in order to use the fall for supplying power to a factory.

HEIGHT OF THE AXIS OF ROTATION OF THE WICKETS.

The wickets of the navigable pass ought not to swing spontaneously around the upper journals of the horses to which they are fastened. M. Chanoine called them non-automatic wickets, in opposition to those of the weir, in his different articles, (Annales, 1855, 1859, 1861, 1868;) and from the beginning he thoroughly explained that if they should happen to swing spontaneously, a serious and dangerous disturbance would result in the levels of the pools, and that, in addition, bodies barely floating or rolling on the bed of the river might stop among the horses, entangling themselves under the breeches of the wickets, and that it would then be difficult to raise the latter.

From this he concluded that the axis of rotation on the horse should be between the third and the half of the height of the wicket, and he placed it at five-twelfths of this height; but this proportion of five-twelfths is not at all absolute; it depends mainly on the level of the lower pool, and should increase in proportion as this level is raised in relation to the axis of rotation. It was, then, very important not to adopt this proportion for the new sluice at Port-à-l'Anglais without examination, as its spontaneous and unforeseen opening would cause a sudden change in the stage of water at Paris; but, on the other hand, the more the axis of rotation is raised, the greater the length of the horse and of the prop, and it was important to reduce to what was strictly necessary the already large dimensions and weights of these important members.

The height adopted results from the following calculation, in which I have limited myself to the consideration of the hydrostatic pressures on the wickets of the water above and below. The other forces, which MM. Chanoine and De Lagrené sought to include, (Annales, 1861, second half-year, pages 278 and following,) the pressure due to the velocity of the water, the weight of the wicket, and the friction, appeared to me to have little importance in the case; they may be neglected in comparison with the hydrostatic pressures, and moreover it is, at least at present, impossible to calculate with any accuracy the pressures due to the velocity of the current, and especially how they are distributed over the different parts of the wicket. It cannot be done without introducing into the calculations co-efficients entirely unknown; besides, there is no serious error in admitting that the resultant of these pressures acts very nearly at the center of figure of the wickets, and that, consequently, its influence, like its lever-arm, is very feeble.

Let H be the vertical height of a wicket, including the lap of 4 inches against the sill;

u, the depth of the sheet of water that pours over its top;

h, the height of the surface of the lower pool above the sill of the dam;

a, the angle which the wicket, when up, makes with the vertical;

C, the vertical height of the breech:

The pressure of the upper water upon a wicket of 3.28 feet in width will be—

$$P = \frac{62.5 \times 3.28\, H\,(H + 2\,u)}{2 \cos a}$$

The lever-arm of this force, referred to the base of the wicket, will be—

$$l = \frac{H\,(H + 3\,u)}{3 \cos a\,(H + 2\,u)}$$

and referred to the axis of rotation—

$$L = \frac{C}{\cos a} - \frac{H\,(H + 3\,u)}{3 \cos a\,(H + 2\,u)}$$

Whence the moment—

$$P\,L = \frac{205\,H\,(H + 2\,u)}{2 \cos^2 a}\left(C - \frac{H\,(H + 3\,u)}{3\,(H + 2\,u)}\right)$$

The pressure of the water below will be—

$$P' = 205\,\frac{h^2}{2 \cos a}$$

The lower arm of this force referred to the bottom line of the wicket, which is 4 inches below the sill, would be—

$$l' = \frac{1}{\cos a}\left(\frac{h}{3} + 0.33\right)$$

and referred to the axis of rotation—

$$L' = \frac{C - 0.33}{\cos a} - \frac{h}{3 \cos a}$$

Whence the moment—

$$P'\,L' = \frac{205\,h^2}{2 \cos^2 a}\left(C - 0.33 - \frac{h}{3}\right)$$

The wicket cannot swing as long as $P\,L$ is greater than $P'L'$; since the ratio $\frac{P\,L}{P'\,L'}$ is independent of the value of the angle a, we can temporarily lay aside the determination of the angle, which will be studied farther on, and can compare the values of $P\,L \cos^2 a$ and $P'\,L' \cos^2 a$ which leads to supposing for the moment that $a = 0$ and $\cos = a\,1.00$.

For the wickets of the Port-à-l'Anglais sluice, on the supposition that $a = 0$, $H = 12.47$, and calling λ the lever-arm of the resultant of the forces P and P' referred to the base of the wicket, we have—

$$P = 15939 + 2556\,u$$

$$l = \frac{155.5 + 37.41\,u}{37.41 + 6\,u}$$

$$P\,l = 66252.6 + 15939\,u$$

$$P' = 102.5\,h^2$$

$$l' = \frac{h}{3} + 0.33$$

$$P'\,l' = 34.17\,h^3 + 34.17\,h^2 = 34.17\,h^2(h + 1)$$

$$\lambda = \frac{P\,l - P'\,l'}{P - P'}$$

To show clearly the variations of λ, I have prepared the following double-entry table, which gives the different values of this lever-arm for the values of u written in the first horizontal line, and the value of h indicated in the first vertical column:

Height of the upper pool above the sill.	Depth of overflow.				
	$u = 0.00$	$u = 0.33$	$u = 0.67$	$u = 1.00$	$u = 1.33$
$H + u - 0.33 =$	12.14	12.47	12.81	13.14	13.47
Height of the lower pool on the sill.	**Lever-arm of the hydrostatic pressures above the base of the wickets $= \lambda$.**				
$h = 8.33$	4.99	5.11	5.20	5.26	5.34
$h = 8.67$	5.03	5.14	5.23	5.31	5.38
$h = 9.00$	5.05	5.16	5.26	5.34	5.41
$h = 9.33$	5.06	5.18	5.29	5.36	5.44
$h = 9.67$	5.06	5.19	5.31	5.39	5.47
$h = 10.00$	5.04	5.19	5.31	5.40	5.48
$h = 10.33$	4.99	5.16	5.30	5.40	5.49
$h = 10.67$	4.88	5.10	5.27	5.39	5.48
$h = 11.00$	4.70	5.03	5.20	5.36	5.47

It will be seen that the length of the lever-arm of the resultant of the hydrostatic pressures of the water above and below the dam, referred to the base of the wickets, increases with the height of the two pools, and that for a maximum lift of 13½ feet above the sill it does not exceed 5.49 feet for a vertical wicket, or $\frac{5.49}{\cos \alpha}$ for a wicket whose angle with the vertical is α.

The sill of the dam being 4 inches above the base of the wickets, I have placed the axis of the upper journals of the horses at 5 feet 2 inches above the sill; it follows from this that the horses have a length of 6 feet 3 inches measured between the axis of their upper and lower journals, and that the vertical projection of the breech of the wickets has a height of 5 feet 7 inches. As the wickets are inclined at an angle of 20° with the vertical, the length of their breech measured along the inclination of the planking is 5 feet 11 inches; that of their chase reaches 7 feet 1 inch or 6 feet 9 inches, according as account is taken or not of the board of 4 inches vertical height, which must be fastened on top, as is the case with the other navigable passes of the Upper Seine, in order to raise the top of the wicket to the normal level of the pool, if it be considered necessary, and if the discharge of the river be too small to supply continuously an overflow of 4 inches.

The wickets thus arranged are still less exposed to swinging spontaneously, since the dam is generally entirely open before the water below rises to 9 feet 10 inches above the sill; that is, to the reference 93.70, for there would then be in the upper pool without any artificial lift a draught of water of nearly 9 feet 10 inches. Moreover, at this stage of water the sudden opening of the Port-à-l'Anglais dam would no longer produce a dangerous change of level in the upper and lower pools; the change in discharge which results from it being not very great.

For this reason, the experiment was made on the 26th of January and 28th of February, 1872, of retarding the opening of the dam; the wickets of the old navigable pass were swung when the water rose to the reference 96.49 above and 92.71 below; that is, to an elevation of 10 feet 4 inches in the upper pool and 6 feet 7 inches in the lower pool above the sill of this pass; and the water was permitted to rise to the reference 96.81 in the upper pool and 94.19 in the lower pool before the sluice was opened; its wickets were thus held in place while the upper pool was 13 feet and the lower pool 10 feet 4 inches above the sill.

It is true that these wickets then began to oscillate on their horses; but after inclining slightly they spontaneously became erect, and not one of them was completely swung. Besides, this alternating pendulous movement was chiefly caused by the current on the up-stream side, and by the eddy, which was caused on the down-stream side by the almost entire opening of the old pass and of the weir, the greater portion of whose wickets were thrown down or swung on their horses.

SPONTANEOUS MOVEMENTS OF THE OLD WICKETS.

We have just seen that the wickets of the old pass (which have a height of 9 feet 10 inches, an inclination of 8° with the vertical, a breech of 4 feet 6 inches, a chase of 5 feet 9 inches, and have the axes of the upper journals of their horses placed at 4 feet 1 inch above the sill) swung spontaneously on the 26th of January, 1872, when the river rose on their sill to 10 feet 4 inches on the up-stream and 6 feet 7 inches on the down-stream side. MM. Chanoine and de Lagrené had predicted this fact very accurately in their memoir published in 1861; for they say (page 292) that the wickets of the La Citanguette dam, which they take as an example, would swing, if the water should rise at any one time on their sill to 10 feet 8 inches up stream and 6 feet 6 inches down stream. Experience has in fact proved that all the navigable passes of the Upper Seine swing when the water rises on the sill to about 6 feet 7 inches below and to 10 feet 2 inches or 10 feet 6 inches above. But the authors of the memoirs suppose (pages 292 and 293) that it is practicable to regulate the pools of the Coudray and the Citanguette dams in such a way that the water shall never overflow their tops by more than 4 inches, and they suppose, besides, that the slope of the pool between these dams will not exceed 6 inches, so that the water would never rise on the sill of the Citanguette dam to more than 6 feet on the down-stream and 10 feet 2 inches on the up-stream side.

In this they committed an error of overestimating, especially in the matter of the slope of the pools, and they concluded wrongly that the wickets of the navigable passes of the Seine would never swing spontaneously; for it is not possible to regulate, within such narrow limits, the height of the waters above and below a movable dam. With a series of dams at regular intervals, such as those which give to the Yonne and the Seine artificial pools between Auxerre and Paris, over more than one hundred and twenty-four miles of length, it happens tolerably often that it is necessary to pass a temporary wave, without opening the navigable passes of the dams, as they would have to be closed again in a few hours later, and this double maneuvering would cause serious disturbances in all the pools, and would cause many inconveniences to navigators.

The water can therefore rise to more than 4 inches, and even to more than 10 inches above the normal levels of the pools, although the regulating weirs may be entirely open. All that is needed to produce this is that a dam be maneuvered too rapidly, or even that a storm, in the valley of the Yonne, should add its waters to a discharge of the river, already a little too great.

On the other hand, even if we admit that the height of the water just above a dam can be regulated at will, the slopes of the pools cannot be controlled, and they increase very rapidly with the discharge as the regulating weirs are opened. Thus the slope of the pool between Le Coudray and La Citanguette, which, by supposition, should not exceed 6 inches, was actually only from 2 inches to 4 inches during the first fortnight of October, 1872; it varied between 1 foot and 1 foot 4 inches during the preceding months of July, August, and September; during the months of May and June of the same year it rose to an average of 1 foot 8 inches, and even reached 2 feet. Notwithstanding, during all this period the level of the water above the Le Coudray dam oscillated sometimes a little below, sometimes a little above, the tops of the wickets.

FLUTTER- (PAPILLON-) VALVES.

We now remedy the inconveniences which are caused by the spontaneous movements of the wickets of the old navigable passes of the Upper Seine by placing between the uprights of their chases little automatic valves called flutter-valves. The same expedient could be used for the large wickets of the sluice, if it should subsequently be desirable to add to their height in order to increase the draught of water in the upper pool to 6 feet 7 inches instead of 5 feet 3 inches, and they should then threaten to swing too easily.

The flutter-valves are nothing but M. Chanoine's automatic weir-wickets, whose dimensions have been reduced so as to make them fit between the uprights of the pass-wickets. They are 3 feet 3 inches in vertical height and 1 foot 5 inches wide; their tops are placed immediately under the cap of the chase, and are 8 inches below the normal level of the pool. When, then, the water rises to 8 inches above this level, each of them supports a weight of water of—

$$\frac{17 \times 39 \times 62.3\,(39 + 2 \times 16)}{1728 \times 2 \cos a} = \frac{851}{\cos a} \text{ pounds.}$$

It is clear that if this little valve opens before the swinging of the wicket which carries it, the pressure on the chase of this wicket will be sufficiently reduced for it to remain up. It will, therefore, suffice if the axis of rotation of the flutter-valve be placed at such a height that it will swing spontaneously before the wicket that supports it; that is, when the water is pouring over this wicket to a depth of from 4 to 6 inches. On the other hand, the spontaneous movements of automatic valves reduced to these small dimensions cause no inconvenience; for experience has proved that one man in a skiff can always shut them without difficulty by means of a simple boat-hook, and no effort has been made to cause them to close spontaneously. They open of themselves, but they would not close of themselves unless the pool fell considerably below its normal level. The lock-tender must therefore set them up by hand before this takes place.

I made the first trial of these flutter-valves at Port-à-l'Anglais, where two were put in place in 1871; then, in 1872, ten were placed in each of the passes of Evry and Le Coudray; finally, at the beginning of this year, I had them placed in the chases of all the wickets of the Coudray pass. In my opinion, these experiments show that these little machines work with great ease, and that they give no trouble, either in maneuvering or in discharging a surplus of water.

They discharge so little that their spontaneous opening cannot make too rapid a change in the levels of the pools, and, on the other hand, they offer many advantages. While they postpone the time for the wickets to swing, they work well with the weir in assisting to regulate the level of the pool, both during medium stages and when the dam is about to be closed.

The discharge of some of the Upper Seine weirs, especially that of Port-à-l'Anglais, which was reduced one-half in 1870, is sometimes insufficient at average stages. The same case holds at Melun, where the navigable pass, 213 feet in width, occupies all of the left channel, and the weir is replaced by a small needle-dam, 131 feet in width, which had formerly been built across the right channel. Although its sill was placed below low water, this small dam, or at least the channel of the river at whose lower end it is placed, does not always suffice for the discharge of the Seine when the dam of the wide channel is closed. The dammed water then rises in the wide channel considerably above the crest of the pass-wickets, even when the small needle-dam is entirely open, and this height cannot be reduced without opening the pass. By placing flutter-valves in the wickets of the Melun and Port-à-l'Anglais passes, the insufficiency of discharge of their weirs will easily be remedied.

On the other hand, it sometimes happens that the fall increases too rapidly during the closing of a navigable pass, and that the raising of the last wickets then becomes difficult, either because the discharge over the weir is insufficient, or because its sill has been placed a little too high. This fact is especially noticeable at Albon, Melun, and Varennes. This inconvenience can in some measure be obviated by opening the flutter-valves as the wickets are raised; the sill of the valves being placed at 5 feet 11 inches above that of the dam, as soon as the water of the pool rises to this level, the discharge of the valves that are open is added to that of the weir, and consequently the difference of level increases less rapidly.

Lastly, experience at the Coudray dam has recently shown another advantage of flutter-valves. When the pass of the dam is closed, and the weir is nearly all open, an eddy begins below the lock, which causes considerable annoyance to boats entering or departing; the river-men, for this reason, have several times requested the construction, below the locks of the Upper Seine, of lines of piles like those which have been placed, with the same object in view, below the locks at Suresnes, Conflans, and other places on the Lower Seine. Moreover, since the wickets of the Coudray Pass have been provided with flutter-valves, there has no longer been any troublesome eddy at the foot of the lock; these valves are left open as long as the weir is not entirely closed, and that suffices to spread the current, in a uniform and regular manner, over the entire width of the river below the dam.

ANGLE OF THE WICKETS WITH THE VERTICAL.

When the wickets are up, the resultant of the pressures which they sustain is decomposed into two forces normal to their faces, of which one is overcome by the resistance of the sill, and the other acts on the top of the horse. The latter, being ordinarily directed in the angle which the prop makes with the prolongation of the horse, is resolved into two others, of which one compresses the prop, and the other tends to tear out the horse and the sill to which it is fastened; it therefore acts with the underpressures, which the floor must resist.

This last component is the most injurious of all to the solidity of the work; it is then quite advantageous to reduce it as much as possible; it evidently decreases as the wickets have a greater inclination with the vertical; and it would be completely done away with if the latter were placed normal to the props. But, on the other hand, in proportion as they are inclined, their lengths are increased, as also the total pressure which they support, and the pressure on the head of the horses; there is, therefore, an opportunity to examine into what is the best slope to adopt, for that of 8° was fixed somewhat arbitrarily by the inventor of dams with movable wickets.

The following calculations, in which I have limited myself, as before, to the consideration of the hydrostatic pressures of the water above and below the dam, caused me to adopt the angle of 20° instead of 8° for the Port-à-l'Anglais sluice; moreover, I have neglected, in this calculation, the counterpressure of the water on the down-stream side, as it may become very small when the river is low; besides, its only effect is to diminish the pressures which the different parts of the works should resist. There is therefore no risk in neglecting it.

Let us preserve the notation already used, and call—

Q the pressure on the head of the horse;

S the component of this pressure in the direction of the prop; and

T the component in the direction of the horse.

The value of Q can easily be found by taking the moments of P and Q around the sill. As 4 inches of the wicket rest against it, the lever-arm of P is—

$$l-\frac{0.33}{\cos a}$$

That of Q is—

$$\frac{C-0.33}{\cos a}$$

Whence—

$$Q=P\left(l-\frac{0.33}{c\quad a}\right)\frac{\cos a}{C-0.33}$$

But we have seen farther back that—

$$P=\frac{15939+2556\,u}{\cos a}=\frac{A}{\cos a}$$

$$Pl=\frac{66252.6+15939\,u}{\cos^2 a}$$

We will then have—

$$Q=\frac{60939.6+15087\,u}{(C-0.33)\cos a}$$

This formula shows incidentally that there is an advantage as regards the resistance of the horse and of the prop in increasing the height of the axis of rotation; this height being determined, and C being made 5.58, we have finally—

$$Q=\frac{11607.54+2873.7\,u}{\cos a}=\frac{B}{\cos a}$$

To find the values of S and T, it is necessary to know the shape of the triangle formed by the horse, the prop, and the floor; for—

$$S=Q\times\frac{\sin\,(Q\,T)}{\sin\,(S\,T)}$$

$$T=Q\times\frac{\sin\,(Q\,S)}{\sin\,(S\,T)}$$

Now, the prop is the hypothenuse of a right-angled triangle, whose height is that of the top of the horse above the floor, and whose base is the length of the horse increased by the space required to seat the tripping-rod and the foot of the prop between the horse when thrown down on the floor and the heurter. It follows from this that the inclination of the prop to the horizon is about 37°.

On the other hand, the inclination of 5° up stream, given in M. Chanoine's model, has been retained for the horse, in order to place the center of gravity of the wickets on the up-stream side of their lower axis of rotation; for, on the one hand, the arrangement facilitates the putting in place of the prop when the dam is raised, and, on the other hand, it prevents the wickets from falling on the floor at the least displacement of the prop, even when there is no water pressure on them, which would be very dangerous for the workmen when putting the wickets in place, either during their original construction or when there is occasion to replace them.

It follows from this that the angle between the prop and the horse is—

$$S\ T = 90^\circ - 37^\circ - 5^\circ = 48^\circ$$

the angle of the horse with the force Q, normal to the plane of the wicket—

$$Q\ T = 85^\circ - a$$

and the angle of the prop with the force Q—

$$Q\ S = 37^\circ - a$$

We then have—

$$S = \frac{Q \sin (85^\circ - a)}{\sin 48^\circ} = \frac{B \sin (85^\circ - a)}{\sin 48^\circ \cos a}$$

$$T = \frac{Q \sin (37^\circ - a)}{\sin 48^\circ} = \frac{B \sin (37^\circ - a)}{\sin 48^\circ \cos a}$$

The angle a causes the forces above given to vary at the same time with the length and the bending moment of the wicket.

The wickets being 12½ feet in height and 8 inches thick, their length is—

$$\frac{12.50 - 0.67 \sin a}{\cos a}$$

To find the bending moment of their wood-work, if a horizontal line be drawn across the planking at a height x below the top, and the moment of the forces acting above this level be taken, we find*—

$$\frac{R\ I}{n} = \frac{62.5\ x\ (x + 2\ u)}{2 \cos a} \cdot \frac{x\ (x + 3\ u)}{3 \cos a\ (x + 2\ u)} = \frac{62.5\ (x^3 + 3\ u\ x^3)}{6 \cos^2 a}$$

This moment reaches its maximum when x represents the height of the chase, or when—

$$12.50 - (5.60 + 0.67 \sin a) = 6.90 - 0.67 \sin a$$

Neglecting $0.67 \sin a$, and taking $x = 6.90$, which will give a bending moment somewhat too great, we find—

$$\frac{R\ I}{n} = \frac{3411.02 + 1483.05\ u}{\cos^2 a} = \frac{D}{\cos^2 a}$$

By means of these formulas, it is easy to take into account the influence of the angle a on the different forces under consideration. The simplest method of so doing is to form the following table, which gives numbers proportional to these forces for the different values of a, and in which—

---

* NOTE BY TRANSLATORS.—R is the pull or thrust on the outermost fibers. I is the moment of inertia of the cross-section; n is the distance from the neutral axis to the outermost fiber. (See Stoney on Strains, vol. 1, p. 44.)

$$A = 15939 + 2556\,u$$
$$B = 11607.54 + 2873.7\,u$$
$$D = 3411.02 + 1483.05\,u$$

Angle of the wickets with the vertical, a.	Length of the wicket— $\frac{12.50 - 0.67 \sin a}{\cos}$	Total pressure on a wicket— $P = \frac{A}{s}$	Pressure on the head of the horse— $Q = \frac{B}{\cos a}$	Compression on the prop— $S = \frac{B \sin (85^\circ - a)}{\cos a \sin 48^\circ}$	Tension on the horse— $T = \frac{B \sin (37^\circ - a)}{\cos a \sin 48^\circ}$	Bending moment of the wood-work of the wickets— $\frac{R I}{n} = \frac{D}{\cos^2 a}$
	Feet.					
0°	12.50	1.0000 *A*	1.0000 *B*	1.3405 *B*	0.80982 *B*	1.0000 *D*
8°	12.53	1.0098 *A*	1.0098 *B*	1.3240 *B*	0.65879 *B*	1.0197 *D*
10°	12.57	1.0154 *A*	1.0154 *B*	1.3198 *B*	0.62033 *B*	1.0311 *D*
15°	12.79	1.0352 *A*	1.0352 *B*	1.3091 *B*	0.52186 *B*	1.0718 *D*
20°	13.06	1.0641 *A*	1.0641 *B*	1.2978 *B*	0.41867 *B*	1.1325 *D*
25°	13.48	1.1033 *A*	1.1033 *B*	1.2858 *B*	0.30862 *B*	1.2174 *D*
30°	14.05	1.1547 *A*	1.1547 *B*	1.2728 *B*	0.18936 *B*	1.3333 *D*
37°	15.15	1.2521 *A*	1.2521 *B*	1.2521 *B*	0.00000	1.5678 *D*

We see that by giving the wickets an inclination of 20° instead of leaving them vertical, we increase their length by 0.56 foot, the total pressure on the head of the horse and on the wicket by 6.4 per cent., and the bending moment of the wood-work by 13.25 per cent., all of which is important; but, on the other hand, the compression on the prop is slightly lessened, and the force that tends to pull up the sill is diminished nearly one-half, (0.42 instead of 0.81.)

This last result is very important, and caused the angle of 20° to be adopted at Port-à-l'Anglais; a smaller value of a would make the upward pull on the sill too great, and a greater value would make the other forces increase too rapidly.

If we suppose the surface of the upper pool to be 1.30 feet above the crest of the wicket, and that of the lower pool to be as low as possible, since its effect was neglected in the calculations, we have—

$$u = 1.30$$
$$A = 19262 \text{ pounds}$$
$$B = 15343.4 \text{ pounds}$$
$$D = 5339 \text{ pounds}$$

By substituting for the letters in the preceding table these values, we form the following table, which gives the amount of the various forces called into play, not by proportional numbers, but in absolute value.

Angle of the wickets with the vertical, .	Length of the wicket.	Strains on the wickets for an overflow of 1.30.				
		Total pressure on a wicket.	Pressure on the head of the horse.	Compression on the prop.	Tension on the horse.	Bending moment of the frame.
	Feet.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
0°	12.50	19262.0	15343.4	20568.0	15642.7	5339.0
8°	12.53	19450.3	15494.6	20315.1	10108.1	5438.2
10°	12.57	19558.1	15580.1	20251.0	9517.9	5505.0
15°	12.79	19940.5	15884.6	20085.9	8007.2	5722.3
20°	13.06	20497.1	16328.1	19913.1	6423.9	6046.3
25°	13.48	21252.1	16929.6	19729.0	4736.5	6651.3
30°	14.05	22240.7	17717.0	19529.1	2905.5	7118.7
37°	15.15	24117.4	19212.0	19212.0	0.0	8370.9

CHAPTER III.

DETAILED ARRANGEMENT AND CALCULATIONS OF THE STRENGTHS OF THE VARIOUS PARTS OF THE STRUCTURE.

The preceding table gives us the means of readily calculating the strength of the different parts of the dam; the figures on Plate 19 show the arrangements that these calculations have caused me to adopt.

WOOD-WORK OF THE WICKETS.

The wood-work of the wickets has been already described. If we neglect the resistance of the planking, the bending moment of each upright will be at the outside—

$$\frac{R\,I}{n} = \frac{6046.3}{2} = 3023.15 \text{ pounds.}$$

The area of the cross-section of these uprights is 1 foot by 0.67 foot; hence—

$$\frac{I}{n} = \frac{1.0 \times 0.67^2}{6} = 0.0748 = R$$

whence $R = 40416.4$ pounds per square foot, or 280.7 pounds per square inch at the utmost. The load borne by the planking and by the transoms is still less; but the wood of the wickets must not be greatly strained if we wish to make it last, because it is subjected to many and powerful causes of injury.

HORSE.

The horses (Fig. 105, Plate 19) are 6 feet and 3 inches long between the axes of the upper and lower journals, 2 feet 6 inches wide at the base, and 1 foot 8 inches at the head, exclusive of the journals. They are made of six pieces of wrought iron, simple in form, and easily put together; each one weighs 420 pounds; their dimensions would scarcely have permitted their construction in one piece with curved cheeks to receive the fastenings of the prop, as in M. Chanoine's model.

The head of a horse is a straight shaft without any eccentricity; its diameter varies from 5 inches for the central portion that carries the prop to 2½ inches at the ends that form the journals. The shape of this shaft thus approximates that of a solid of equal resistance; for it works like a beam fastened at the middle. The flanges, between which the prop is held, are provided with studs, which allow the prop to move toward the slide, but prevent any play in the opposite direction.

The foot of the horse, like the head, is a cylindrical shaft, terminated by journals. This shaft is 3 inches in diameter, and the journals are 2½ inches.

The posts are of wrought iron, 1½ inches by 3 inches. They have an eye at each end, through which pass the ends of the shafts. A riveted key is sufficient to hold them together. Besides, the posts are connected by two transoms 1½ inches in diameter, riveted at the ends.

We see from the above table that the tension on the horse cannot exceed 6,424 pounds. The posts, being in cross-section 2 × 1½ inches × 3 inches = 9 square inches, appear at first glance too strong, since they support less than 750 pounds per square inch; but they have frequently to withstand shocks or very much greater strains; thus, when the wickets are raised, the resultant of their weight and of the pull tends to compress the horses, and the same thing occurs when the wickets are swung; hence, it was necessary to make the horses very stiff, so that they would not lose shape under any circumstances whatever. From this last point of view, it might perhaps have been well to have replaced the two transoms by a cross-bar. As for the head of the horse, its dimensions have been determined for the maximum strain it may have to bear.

The last table gives for the total pressure of the wicket on this member 16,328 pounds, or a strain on each journal of about 8,200 pounds, acting at one foot from the bearing on the prop. On the other hand, the reaction of the horse may reach 6,424 pounds, or 3,200 pounds for each post, acting at 8 inches from the bearing. These forces give two moments: $8200 \times 1.0 = 8200$ foot-pounds, and $3200 \times 0.67 = 2144$ foot-pounds; the axis of the first lying in the plane of the wicket, and of the second normal to the horse. The parallelogram of forces gives a resultant moment of about 8,900 foot pounds, and we have, for the shaft forming the head of the horse—

$$\frac{R\,I}{n} = 8900$$

the radius of this shaft being 0.215 foot—

$$\frac{I}{n} = \frac{\pi\, 0.215^3}{4} = 0.0062$$

whence

$$R = \frac{8900}{0.0062}$$

or 10,000 pounds per square inch at the outside. The shearing-strains supported by the journals are very small.

PROP.

We have seen that the prop may have to resist a compressive strain of 20,000 pounds. It becomes then a matter of the greatest importance that this strain should be directed exactly along the axis of the prop; consequently, the bend at the upper end in the original model has been abandoned.

The object of this bend was to leave under the prop when the wickets were down the necessary height for the tripping-rod; the same result has been obtained by slightly lowering the floor. When a wicket is down, it rests on four stone blocks that project a little above the floors; besides, the chase is held up by two cleats on the stiles; by this very simple arrangement, the wicket is perfectly supported, no warping of the woodwork is to be apprehended, and, finally, the horse and prop, although straight, are held above the tripping-rod, and cannot interfere with its movements, as shown in Fig. 102, Plate 19. The prop is only a connecting-rod, of which the horse is the crank; hence, its hand has the shape used for connecting-rods. It is attached to the horse by a strap and keys, through which is passed a bolt. These keys support all the pulling strains, and the bolt only prevents the strap from opening. This arrangement was borrowed from the plan designed by M. Hirsch for dams on the Saône; but in his plan, the head of the horse was eccentric, which made its shape very complicated and very hard to fashion. This eccentricity was not used at Port-à-l'Anglais.

The prop is 3½ inches in diameter, with a sectional area of 12¼ square inches. It will sustain, at the outside, 2,100 pounds per square inch;

and the ratio of its length to its diameter is 40. The prop should be lightly loaded; for, although it is straight, we cannot be sure that the pressure it sustains will always act exactly along its axis of figure; it may be thrown slightly out of its normal position, and the slightest deviation will greatly increase the strain of 2,100 pounds.

The props weigh about 600 pounds apiece; but the greater part of this weight is placed near the lower end, as shown in the drawing, so that the current may not be able to raise them at the time of closing the dam by moving them from the point of rest that they should then have against the heurter.

ARRANGEMENTS AND FASTENING OF THE SILL.

The sill is made of three pieces of wood instead of a single one, 15 by 18 inches, as in the original model; for the inclination and thickness adopted for the wickets would have given too great a sectional area for a single piece.

The first of these pieces holds the journal-boxes of the horses. Its cross-section is 12 by 16. A rod, 2 inches in diameter, runs through it in the plane of the axis of each wicket, and fastens it to a cast-iron disk 20 inches in diameter, placed beneath the masonry, 10 feet below the sill; the upward component on each horse being at the outside 6,424 pounds. These rods only bear 2,045 pounds per square inch, and the volume of masonry resting on the cast-iron disks is quite sufficient to resist any lifting efforts.

A second string-piece, placed on top of the first, receives the pressure of the horses, and a third receives the shock of the wickets when the raising is finished. This last is the real sill of the dam.

These three pieces of wood bind together the cut stones of the floor. They are connected with each other and with these stones by iron straps, (Figs. 102, 103, Plate 19.) This system of timbers covering the cut stones, and themselves partly covered by bands of plate-iron, is, perhaps, somewhat complicated; but it appeared necessary, on the one hand, to avoid any shock coming upon the stone without being deadened by the elasticity of an intervening piece of wood, and, on the other hand, in order that boats (when the dam is open) and the wickets (when the dam is being opened) may not rub on the timbers or the stones, but only on the coverings of iron; and, lastly and chiefly, in order to insure the union of all the cut stones of which the sill is formed.

COLLARS AND JOURNAL-BOXES OF THE HORSES.

The original model of the collars by which the wicket is fastened to the head of the horse has been preserved almost unchanged; only the dimensions have been somewhat increased, and the projecting shoulders, designed to limit the inclination of the wicket when swung, have been abandoned, because the usefulness of these shoulders has not been well shown, and, on the other hand, under certain circumstances, they present the disadvantage of increasing greatly the force required to raise the wickets. Each of the collars weighs about 55 pounds.

The shape of the sill has caused the cast-iron journal-boxes, that, in the original model, received the lower journals of the horses, to be replaced by plumber-blocks of the pattern ordinarily employed to support horizontal shafts. Experience shows that it is almost always necessary to use a diving-dress to take up the wooden wedges that close the old-fashioned journal-boxes, and I thought that it would not be more difficult for a diver to unscrew a few nuts than to take up these wooden wedges; but the nuts may become rusty, and it may be difficult to remove them; and although rust does not generally attack iron constantly submerged, it might have been better to retain the pattern of the old boxes, and to modify them to suit the form adopted for the sill. I regret not having done this.

HEURTERS, SLIDES, TRIPPING-RODS.

The heurters and slides, the tripping-rod, its supports and capstans, are very nearly in conformity with the original models of M. Chanoine, except as to their dimensions, which have been very much increased.

Besides the unequally-spaced shoulders, which act successively on the props when the wickets are lowered, the tripping-rod is provided with equally-spaced counter-shoulders, which at the same time cover all the slides when the rod is not in use. This very simple arrangement, devised by M. Lambert, agent of the second class, does not permit any unexpected escape of the props from the heurters, as sometimes happened in the old navigable passes; moreover, experience shows that there is no inconvenience attendant upon it. The tripping-rod is much heavier than it should be, as the contractor did not cut away the parts between each catch and its counter-catch to the extent contemplated by the plan, and it resembles the notched rods used on the Marne for the weirs of M. Leuiche Desfontaine's system, except that, on these weirs, the props rest on the solid part of the rod; whereas, at Port-à-l'Anglais, they are held between the notches. The tripping-rod weighs 27 pounds per running-foot; this great weight gives no trouble, provided that its center of gravity be on the line of supports; on the contrary, it is very useful to have the bar of a size proportionate to the strains it may have to undergo, and for this reason the idea of using special U or double T-irons was abandoned.

Objections have frequently been made to M. Thénard's system of tripping-rods, used in M. Chanoine's dams; but actual experience shows that these rods work very well, except in case of accidents, that could not be foreseen, or of faults in the first construction; only they must be of a size sufficient to easily overcome friction, and remove the gravel that may surround them. It is sometimes necessary to use a great deal of strength on the maneuvering-capstan; hence, their dimensions must be proportional to the power of the capstan, and the size of the gravel that may hinder their motion; their joints must also be simple, and the bolts fastening the parts together must be keyed, for the bars frequently vibrate through the effect of the fall of water, and in this case the assembling-nuts become unscrewed spontaneously. These considerations must cause the rejection of special and light irons for the tripping-rods, and the adoption, on the contrary, of solid and heavy irons.

Finally, the tripping-rod is but an accessory, and in no way an essential element of wicket-dams; and when, by chance, it cannot work, the dam is easily opened by letting down the wickets one by one with the maneuvering-boat in like manner as they were raised. For this purpose, it is sufficient to first reduce the difference of level by opening the weir, which has always been an easy operation since the foot-bridges have been constructed; the only effect is to cause an unimportant delay in the maneuver.

SERVICE-BRIDGE.

It did not seem to be prudent to rely on a maneuvering-boat to raise the large wickets of the pass at Port-à-l'Anglais, and a service-bridge formed of trestles like those of M. Poirée, has been constructed on their up-stream side, but the only use of the bridge is to carry the windlass that maneuvers the wickets, as had already been done for the wicket-dams on the Marne and Saône; it was, in fact, a return to M. Chanoine's original idea, experimented upon by him in 1853 at Courbeton, at the time of his first trials with wickets swinging on a movable horse.

It may, at first sight, seem astonishing that a service-bridge should be necessary for the smallest wickets, (those of the weir,) and for the largest, (those of the sluice;) and that the maneuvering-boat should be retained for the dam proper, or the old navigable pass, where the wickets are of an intermediate size. The explanation is simple and perfectly logical.

It is first necessary to throw out of question weirs closed by small wickets 6½ feet high, because they are not at all under the same conditions as navigable passes of larger dimensions. The wickets of a navigable pass must always be either wholly opened or wholly closed. They should always be raised, without causing a rise of the water-surface; or, at least, they should cause a very slight one, which, in principle, allows the use of a maneuvering-boat. The weirs, on the contrary, serve to regulate the level of the pool, and must be maneuvered under the normal fall at the dam, either when they are swung or when they are set up. It is this condition that necessitates the establishment of a service-bridge, because a boat could not be safely kept above wickets swung, or ready to swing, spontaneously; that is to say, at the head of a cataract of at least 6½ feet fall, and in a current of great velocity, which forms very dangerous whirlpools.

To thoroughly elucidate this point, I think that I ought to reproduce, at the end of this article, a note which I prepared at the close of 1868 on the subject of the changes which experience had shown to be necessary in the weirs on the Seine. Fig. 98, Plate 18, shows the bridges that were added in 1868 to all the weirs on the Seine, in conformity to the plan that I was charged with preparing, and which was approved, without change, by the decision of March 8, 1869.

So far as the passes are concerned, it is evidently a matter of great importance to avoid the construction of a service-bridge, and, as far as possible, to maneuver the wickets with a boat; for, besides the additional expense of a bridge, its presence has the disadvantage of greatly retarding the opening of the dam, since, after having thrown down the wicket, the trestles must be let down one by one. Now, it is sometimes necessary to perform the maneuvers very rapidly, on the arrivel of a flood or of floating ice. In this last case, the opening of a wicket-dam without a bridge is easily accomplished, and has been done several times on the Upper Seine, without the last inconvenience, by means of the tipping-rod, although the river was full of floating ice above the dam; but, on the contrary, the lowering of the trestles under the same circumstances is a very long and difficult operation.

The maneuvering-boats, designed by M. Chanoine to raise wickets 10 feet high, are perfectly planned, arranged, and equipped to do their work. They seem, at first sight, to be rather small and weak for the machinery and crew that they have to carry; but they are intended to rest against the perfectly firm screen formed by the wickets already in place, and their dimensions are proportioned to those of the wickets. If the boats were made larger they would be too strong and heavy, and the wickets might be broken in maneuvering. This important consideration shows why we can no longer rely on a boat to maneuver the larger wickets; for we would have to increase the tonnage of the boat much more rapidly than the dimensions of the wickets, in order that its crew might work in safety. The strength of the boat would no longer be in proportion to the strains from the maneuvering-machinery, and the latter might be broken at any movement of the boat, and it would be difficult to rest it against the wickets already up.

Anchoring the boat above the dam has been tried, it is true, especially at the dams of the Belgian Meuse, instead of resting it against the wickets already raised, so it might lie with the current and not across it; but this arrangement seems to me to involve the very disadvantages just mentioned. The boat being alone in the middle of the current, instead of resting against a perfectly firm support, must necessarily be of much greater tonnage. Although it be fastened by a number of ropes stretched taut, these ropes will still be elastic; and when a wicket is pulled, the power exerted is no longer confined to the boat and the workman. If the boat becomes unsteady, it acts by its weight and the elasticity of the long anchoring-ropes. The power applied to the wicket may then become sufficient to break it, instead of merely raising it. Besides, the dam-tenders are at a distance from the wickets, and cannot watch their movements, nor be sure that the prop is tightly in place against the heurter.

It is probable that we might still have got along with a maneuvering-boat at Port-à-l'Anglais for raising the wickets of the sluice, for experience has shown that this maneuver does not require a much greater force than for wickets of 10 feet in height; but we will see further on that special circumstances demanded the construction of a service-bridge at Port à-l'Anglais on the up-stream side of the large wickets.

DIMENSIONS AND ARRANGEMENTS OF THE TRESTLES.

The only special feature of the trestles of the bridge consists in their being much larger than those that up to that time had been built; they are 15 feet 9 inches in total height, while those of the needle-dams of the Lower Seine are only 10 feet 10 inches, and those of the bridges of the wicket-dams on the Saône are about 13 feet. Their weight is proportionately still greater than their height, for each of them weighs 1,350 pounds; but that gives no trouble; they are raised and lowered by a very light windlass, and this maneuver is very easy, because, since the center of gravity of the trestles is quite low, the strain on the windlass is inconsiderable.

Finally, whatever be the size of a trestle, it is always easy to set it firmly, and to maneuver it with the assistance of a windlass; and it is evidently not the size of the trestle, but that of the needles, which limits the height that can be given to Poirée needle-dams. In the case in question, the trestles are only intended to support the windlass for maneuvering the wickets; nothing, therefore, prevents their being of the necessary size and strength, no matter what may be the height of the lift, or the weight of the wicket to be maneuvered.

The only trouble with large trestles comes from the recess in the floor which is to receive them when they are down; for deposits of one kind or another may form there, and it must be cleaned out before the dam can be opened. The depth of this recess increases very rapidly with the size of the trestle, because, when they are down, their slope is proportional to their thickness, and inversely as their distance apart.

At Port-à-l'Anglais this depth is 2 feet; on the other hand, the floor of the bridge is placed 19 inches above the mean surface of the pool, or 4 inches above the highest level that it is thought it can reach; hence, the total height of the trestles is 12 feet 2 inches + 2 feet + 1 foot 7 inches = 15 feet 9 inches.

They form a trapezoid, of which the upper base, which carries the floor, is 4 feet long; the lower base, or axle, 10 feet 2 inches; the up-stream post, being vertical, 15 feet 9 inches; the down-stream post is inclined at 5 vertical to 2 base; and the brace, 3 vertical to 2 base.

It is essential to the solidity of the wickets that the brace should have a considerable inclination. In this case, its inclination was determined by the double condition that the wickets should not touch the trestles in any of their maneuvers, and that the chain fastened at one end to the wicket and at the other end to the windlass on the bridge, should be at an angle of 45°; which is the best arrangement to facilitate the raising of the wickets. It follows from this condition that the distance of the bridge from the sill of the wickets increases with the dimensions of the latter. This is why, in Fig. 94, Plate 18, the bridge of the sluice is farther from the wickets than that of the weir.

Besides the brace, the trestles are stiffened by three horizontal transoms and a fourth inclined one, forming with the brace a Saint Andrew's cross. Except the lower axle, which is a cylinder 3 inches in diameter, all the pieces composing the trestle are of U-iron, as in the Saône trestles; but these irons are 3 inches in height, 1⅓ inches broad, and ¼ inch thick, and weigh 5.4 pounds per foot; while the size of the irons taken on the Saône is $\frac{2\frac{1}{2} \times \frac{1}{4}}{1}$ and they weigh 3.85 pounds per foot.

For equal weights, U-irons have much greater transverse strength than square, or even T-irons, or the cross-shape adopted for the trestles of the Lower Seine, since the material is farther from the neutral axis. The joints are more easily made, and the weight of 5.4 pounds per foot is less than that of the 1½ by 1½ employed in the construction of M. Poirée's small trestles. Figs. 102 and 109, Plate 19, show the arrangements of the trestles at Port-à-l'Anglais; all the joints are stiffened by large bracket-plates of sheet-iron, 0.3 inches thick, and, in addition, by wrought-iron knees at the four corners of the trapezoid. The knees of the upper angles have gudgeons, on which are placed the transoms or claw-balks, that answer for rails for the maneuvering windlass, and the hooks, called link-catches, that hold the maneuvering-chains of the wickets; the up-stream angle has, besides, an iron post that holds a rope forming a hand-rail for the service-bridge.

TO DETERMINE THE STRENGTH OF THE TRESTLES.

It was very difficult to determine in advance the power required to raise the wickets, since this power depends principally on the velocity of the current and on the difference of level at the time of closing the last wickets; and this velocity, and especially the resulting resistances, are scarcely, if at all, known.

From the approximate calculations that can be made on this subject, and especially after the experience at other dams, it has been conceded that the power required to be exerted on a wicket from the foot-bridge would never reach 6,618 pounds; and experience has fully confirmed this estimate. Moreover, this weight of 6,618 pounds is nearly what the trestles would sustain if there were placed against them, not needles, which undoubtedly could not be handled, but temporary shutters, to retain the backwater, in case of necessity, without the help of the wickets, should any of the latter need repairs.

In fact, if the water should then attain its maximum level of 13½ feet above the sill, the pressure on the top of the trestles per running foot would be—

$$62.5\frac{13.45^2}{6} = 1884.6 \text{ pounds,}$$

and 6784.6 pounds per trestle, since they are 3.60 feet apart from axis to axis.

The trestles have, then, been placed so that each one could support at its cap a pull from the maneuvering-chain of a wicket of 6,618 pounds, under an angle of 45°; besides, the strength of each one of the parts has been calculated separately, without considering the ties that hold all the members together, and they could sustain casual strains three or four times as great. In fact, it is necessary to make allowance for the shocks that may occur under certain circumstances.

The top transom being a U-iron of 5.4 pounds per foot, its section is about 1½ square inches under a tension of 6,618 pounds × cos 45°; the strain on this piece is then only 3,100 pounds per square inch.

The down-stream post makes an angle of 21° with the vertical, or 24° with the maneuvering-chain, which is never far from 45°. A force of 6,618 pounds applied to this chain may give, on the down-stream post, a compression of—

$$6618 \text{ pounds} \times \cos 24^\circ = 6046 \text{ pounds.}$$

On account of the great length of this piece, notwithstanding that it is stiffened by three transoms, it is made of two U-beams, placed back to back and riveted together, and the entire section is 3.1 square inches, and the strain is 1,950 pounds per square inch. It seemed necessary not to put a heavy load on this piece; for, should it bend, the strain on the brace might be too great.

The brace makes an angle of 32° with the vertical. The pull at the top exerted by the trestle-cap is decomposed into a compression on the brace and a tension on the up-stream post, which, for the first, may amount to—

$$\frac{6618 \times \cos 45^\circ}{\cos 58^\circ} = 8830.8 \text{ pounds,}$$

and, for the second, to—

$$\frac{6618 \times \cos 45^\circ \times \sin 58^\circ}{\sin 32^\circ} = 7489 \text{ pounds.}$$

The brace being made of two U-irons set back to back, the maximum compression will be about 2,853 pounds per square inch; furthermore, the stiffness of the down-stream post will diminish this compression.

The section of the up-stream post is but 1½ square inches; hence, the tension may be as high as 4,993 pounds per square inch. That is not much for the trestles, but it requires that their sills be firmly fastened. For this purpose, the pattern of cast-iron journal-boxes of the Suresnes dam was adopted. These are bedded in the cut stones of the floor. Furthermore, all these stones are joined together, partly by a wooden stringer, which may be used, if necessary, as the sill of temporary shutters, resting against the trestles, and partly by a band of U-iron, which holds the nuts of the anchors that descend below the masonry as at the sill of the wickets, (Figs. 102, 103, 106, Plate 19.)

The vertical component of a pull on the maneuvering chain of 6,618 pounds would produce, on the down-stream post, a compression of 6,044 pounds, and the horizontal component of the same force would produce, on the brace, a compression of 8,868 pounds. If we add the vertical components of these two forces together, we find that the axle of the trestle may have to sustain a strain of about 13,500 pounds, acting at about 4 inches from the point of support on the down-stream journal-box. For a length of 10.17 feet, the bending moment of the axle would then be—

$$\frac{RI}{n} = 13500 \text{ pounds} \times \frac{0.33 \times 9.84}{10.17} = 4310.4 \text{ foot-pounds},$$

and with the dimensions adopted for the end of the axle (0.26 by 0.26) we would have—

$$R = 6 \times \frac{4310.4}{0.26^3}$$

or 9677.7 pounds per square inch.

This strain is large; and to stiffen the axle, there is placed, as near the down-stream journal-box as possible, a semi-cylindrical bolster, which reduces the span to 1.80 feet instead of 10.17 feet; if the axle should bend so as to touch this bolster, we shall then have—

$$\frac{RI}{n} = 13500 \times \frac{0.33 \times 1.47}{1.80.} = 3638.2$$

and $R = 8325$ pounds only. Nevertheless, in certain cases, the axle will still be, as in all constructions of this kind, the piece on which the greatest strain comes.

The rails that carry the raising-windlass, and serve at the same time as claw-balks to connect together the consecutive trestles, are also heavily strained, since their weight, and consequently their size, cannot be increased beyond a certain amount. Moreover, these pieces are easily replaced. Each of the truck-wheels on the down-stream side of the windlass may exert a pressure on the rails of—

$$\frac{6618 \cos 45^\circ}{2} = 2339.8 \text{ pounds}.$$

Again, these wheels are 2 feet apart, and the trestles 3.60 feet, whence—

$$\frac{RI}{n} = 2339.8 \times \frac{1.0 \times 2.60}{3.60} = 1689.87 \text{ foot-pounds};$$

the cross section of the rails being 0.23 by 0.115,

$$\frac{I}{n} = \frac{0.115 \times 0.23^2}{6} = 0.001014$$

and $R = 10119.2$ pounds per square inch.

Now, besides the pull of 6,618 pounds never being attained, the above calculation simply supposes the rails to be placed on two supports, while in reality they are almost inclosed by the assembling gudgeons.

Each claw-balk weighs 69 pounds, and is 3 feet 7 inches long, with a section of $1\frac{5}{8}$ by $2\frac{3}{4}$.

These balks are not arranged to support needles, but only to sustain the maneuvering-windlass. This is why their depth is greater than their breadth; whereas the reverse would be the case were they to support needles.

CHAPTER IV.

CONSTRUCTION OF THE WORKS.

The works begun in the beginning of May, 1870, were interrupted by force of circumstances on the 14th of September, the evening before the investment of Paris by the German army, when but a few days more were needed to finish, within the limits of the coffer-dams, the fitting of the wickets and the floor; but, by reason of certain circumstances, the coffer-dams were again pumped out on the 17th of October, and all parts of the work below the ordinary level of the water were finished on the 22d of October. The dam was closed the next day, and the coffer-dams were then taken down and removed before the winter-floods, which would, undoubtedly, have overturned them. The upper portion of the piers, the abutments, and the shore-revetments were finished in July and August, 1871.

The ground on which the foundations rest is a bed of foliated calcareous rock, characterized by numerous fossil shells of *Cerite*, which determine its geological position to be in the upper stratum of the coarse Parisian limestone, in which Lias is found.

This calcareous bed has been worn down at Port-à l'Anglais to the reference 76.44 of the general levels of France, or 7.22 feet below the sill of the sluice. The piles and sheeting-piles, driven with heavy rams, scarcely penetrate it to the depth of the shoe, and it is absolutely impossible to dredge it under water, although it is easy to break it up with a pick within coffer-dams. Now, two trenches of about 3.3 feet in depth had to be dug to receive the anchors for the sills of the wickets and trestles.

Therefore, the nature of this ground would not allow the floor of the dam to be set on a bed of béton of sufficient thickness, on which the coffer-dams could be placed, and foundations of ordinary masonry had to be carried down to the solid rock in like manner as the excavations.

This state of affairs materially increased the expense, especially for coffer-dams and excavations; but the floor thus formed is much more solid than if it were founded on a bed of béton, which is never perfectly tight. The ground having been dredged to the rock before building the coffer-dams, the latter were found to be sufficiently tight; and the bottom of the excavation not showing any springs of importance, the masonary was well and easily laid. One particular circumstance must, however, be mentioned.

The limestone-bed, instead of being nearly horizontal, as the dredging seemed to indicate, showed a large hole of nearly 6½ feet in depth, filled with gravel, bowlders, sand, and rubbish of all sorts. This hole, being on the down-stream side of the former floor of the weir, was undoubtedly formed by an old scour, and was afterward filled up by fragments broken off from the stratified rock, and rolled down the slope of the weir. The foundations could not be put on this mass; consequently, this ditch had to be cleared, and then refilled with masonry. This caused an unforeseen increase of $1,590.76 (8,552 francs 50 centimes) in the cost of the masonry.

The only difficulty presented by the work was in joining the new pier to the portion of the weir left standing. The coffer-dam on the side toward the river was placed normal to the weir, and the ends of the masonry of the weir extended as far as the middle of the coffer-dam; in addition, the material taken from the excavation was thrown into the angles formed by the coffer-dam and the weir on the up and down stream sides of the latter. Thanks to this arrangement, after the masonry contained within the coffer-dams was finished, a part of the inner wall of the outer coffer-dam could be removed, and the excavation could be continued up to the masonry of the weir, so as to connect it with the pier of the sluice without causing too much leakage.

The cost of the undertaking, and the total expense of the work, was placed at $41,850 (225,000 francs) by an official statement of August 5, 1872. This cost was distributed as follows; deduction being made of the profits of the contractor:

1. Dredging and earth-work	$1,263 77	
2. Coffer-dams	6,120 80	
3. Excavations	2,932 46	
4. Carpenter's and smith's work on the wickets, trestles, sill, floor, and tripping-rod	11,137 56	
5. Masonry for the floor	6,042 44	
		$27,497 03
6. Masonry below the floor to fill an old scour	1,591 77	
7. Masonry of the piers, abutment, riprap around the abutment, and tearing down the old abutment of the weir	6,280 64	
8. Foot-bridge above the weir	2,105 67	
9. Contingencies	4,374 89	
		14,352 97
		41,850 00

If we would ascertain the net cost of a running-foot of the dam, we must only consider the first five items of the above list; for the rest are independent of the length of the dam. Item 6 is, as we have seen, an exceptional expense, due to an unforeseen cause. The foot-bridge above the weir is a structure altogether foreign to the new sluice, and so is the greater part of the sum estimated for contingencies, which was devoted to various purposes belonging rather to the lock, the dam, and the weir than to the new sluice. The portion of this contingent sum chargeable to the sluice is, moreover, fully balanced by the share of the expenses for coffer-dams, excavations, and maneuvering-capstans for the tripping-rods, which should be included with the piers and abutments, and which it would be difficult to separate from the first four items of the above list. We may, then, estimate the expense of a running-foot of the dam, exclusive of piers and abutments, at—

$$\frac{\$27497.03}{94.16 \text{ feet}} = \$292.02$$

According to MM. Chanoine and de Lagrené, (Annales, 2d half-year, 1868, p. 408,) the expense incurred for the twelve dams of the Upper Seine gives on an average, per running-foot of navigable pass closed by wickets, of 9.84 feet, $178.36, and per running-foot of weir, $82.32, exclusive of piers, abutments, &c.

On the other hand, the average cost per foot of the service bridges built in 1869, above the weirs at Le Coudray, Evry, and Ablon, was $22.06, which makes the cost of a running-foot of weir closed by wickets of 6.56 feet height with a service-bridge about $104.38.

CHAPTER V.

MANEUVERS OF THE DAM—PRACTICAL RESULTS.

The dam at Port-à-l'Anglais has been working steadily since the latter part of October, 1870; it has been maneuvered without difficulty every time that the needs of navigation have required it to be opened, or to be partly or entirely closed, according to the depth of the water; and this experiment of more than two years can be considered as complete; for, during this time, the river has undergone all the variations of discharge that can occur, besides several sudden floods and two attacks of ice, coming down with unusual swiftness, have been borne without trouble.

The following table shows the maneuvers performed since the latter part of October, 1870:

Date of maneuvers.		Remarks.
Dam closed.	Dam opened.	
October 23, 1870	November 11, 1870	Small rise.
December 5, 1870	December 25, 1870	During the night of December 24 and 25, an enormous mass of ice, bearing the remains of boat-bridges, against which it had accumulated, reached the old pass and swung the wickets. Nevertheless, on December 25, the pass was opened by the tripping-rods, although the Seine was frozen over above the wickets, from Ivry Bridge to near Choisy-le-Roi. The wickets of the sluice and of the weir remained closed or swung; the trestles of their bridges being held fast in the ice. Breaking up of the ice January 20, 1871. Rise in February.
March 8, 1871	April 22, 1871	Flood and suspension of navigation during the insurrection of the Commune in Paris.
June 6, 1871	July 8, 1871	Completion of the lock and the sluice.
July 17, 1871	July 20, 1871	
July 29, 1871	August 1, 1871	The maneuvers on July 17 and 29 were made for the benefit of navigation at the request of the barge-captains. Final establishment of continuous navigation by means of dams between Paris and the junction of the Burgundy Canal with the Yonne at Laroche.
August 24, 1871	December 8, 1871	During the night of December 7 and 8, the Seine was almost instantaneously covered with ice under the influence of a temperature of —20°; the old pass was opened on December 8 by means of the tripping-rods; the trestles of the sluice and of the weir were frozen in and remained standing.
December 19, 1871	January 26, 1872	Flood. The wickets of the old pass swung before the dam was opened.
February 4, 1872	February 28, 1873	Flood. The wickets of the old pass swung before the dam was opened.
May 8, 1872	October 20, 1872	During this period, sometimes a few wickets of the weir were swung and sometimes needles were put over some of the intervals between the wickets of the sluice and of the old pass. Lowest water on down-stream side of dam 86.28; greatest difference of level 9.74 feet on October 8, 1872.
November 8, 1872	November 13, 1872	Great flood, which rose on December 17, 1872, to reference 108.00.
May 8, 1873		

All the maneuvers mentioned in this table were performed without difficulty. The power required to raise the large wickets of the sluice did not seem to be much greater than for the wickets of 9.84 feet of the old pass; and it appears, if this point of view alone be considered, that the cost of constructing a bridge above the sluice might have been saved, and that the wickets might have been maneuvered by a boat: but this bridge is indispensable, when the dam is to be entirely closed, on account of the relative proportions adopted for the three sections into which it is divided.

CHAPTER VI.

NECESSITY FOR DIVIDING MOVABLE DAMS INTO SEVERAL PASSES OR SECTIONS.

It is a matter of essential importance to the proper working of a dam to carefully consider the water-way given by the various parts of which it is composed, as was indicated by MM. Chanoine and de Lagrené in their memoir of 1861, (Annales, 1861, 2d half-year, p. 211.) This water-way must suit all stages of the river; hence, several conditions must be simultaneously considered.

The total length of water-way of the dam is determined as for bridges by considering the greatest floods, so that the dam may not cause any backwater on the up-stream side. Regarding it in this light, the height of the sill or sills of the various sections of the dam is of little importance, since their level never differs much from that of the bed of the river in the vicinity. But such is not the case if we consider the river at average stages; for the fall may then become sufficiently great to impede navigation before it is time to close the dam, if its floor or its different parts be placed too high. This is what was specially noticed at Port-à-l'Anglais before the construction of the new navigable pass.

On the other hand, the cost of building a movable dam increases very rapidly with the height of the pool above the sill; hence, we must reduce the length of the navigable pass to the minimum dimensions that will supply the needs of navigation.

If the dam be only composed of two sections, as on the Seine, the Yonne, and the Marne, the length of the navigable pass being limited to the needs of navigation, the length of the water-way of the weir will be fixed by the consideration of the floods. The dams on the Marne were built in this way; but the sill of the weir being much higher than that of the pass, it follows that the fall through the pass increases rapidly as the water becomes low; that it impedes navigation before it is necessary to close the dam; and, finally, that it makes the raising of the wickets a difficult operation. This trouble seems to exist on the Marne, although, as a rule, foot-bridges have been placed above the passes, and the wickets are left swung as fast as they are raised, and are set up afterward, when all the props are bearing against their hurters, so that the fall may not be greater when the last wicket is raised than it was at the beginning.

To provide against this trouble, which he foresaw, M. Chanoine gave to the navigable passes of the Seine a much greater length than that required for navigation. He also closed the weirs by wickets twice as high as those used by M. Louiche-Desfontaines on the Marne; that is, the sills of the weirs on the Seine were placed at less elevation above low water than on the Marne.

This solution has increased the expense in proportion to the length of the navigable passes, and it is less easy to regulate the levels of the pools than it would be were smaller machinery used for closing the weirs; and, notwithstanding this modification, the water-way of some of the dams on the Seine, such as those at Port-à-l'Anglais, Albon, Melun, and Varennes, is still too small. When the river is about 3 feet above low water, and the pass is open, navigation through it becomes difficult; the operation of closing the pass is equally difficult; and, when the pass is closed, it is sometimes hard to regulate the level of the pool, as was mentioned in speaking of flutter-valves.

The Port-à-l'Anglais dam is much better arranged, since it has been divided into three sections with sills at different levels.

The sluice is 94 feet 3 inches wide, which suffices for navigation; and, as its sill is much lower than that of the portion of the former weir which it replaces, the water-way of the dam at low and mean stages is much greater than before it was constructed. The fall over the dam is always very small when it is open, whatever be the height of the water.

But, on the other hand, the sluice having been constructed at the expense of the weir, if it should be entirely closed before the old navigable pass, the weir would no longer suffice to carry off the water of the river while this pass was being closed, and a considerable fall would be formed before the end of the maneuver, and the last wicket could not be raised. To avoid this trouble, the wickets of the sluice, during the closing of the old pass, are left swung on their horses, their breech-chains being fastened to the trestles of the bridge; when the old pass is closed, the wickets of the sluice are set up by hauling with the windlass on the chase-chains, and this maneuver is performed with sufficient rapidity to be completed without the upper pool rising too much.

The three sections are thus closed without causing any appreciable fall: first, the trestles of the sluice and of the weir are raised; then, the wickets of the weir, and afterward those of the sluice are swung, all without sensibly contracting the water-way; then the old pass is closed, the wickets of the sluice are set up, and finally as many of the weir-wickets as may be necessary in order to raise the upper pool to its normal level.

In order to prevent this level from being too high even when the weir is completely open, flutter-valves are now used in the wickets of the old pass, which will afford a remedy for the reduction in the length of the weir.

In opening the dam the inverse order is followed; as the discharge increases, the wickets of the weir are first swung, then the old pass is opened by the tripping rods, the fall having already been much reduced, and when the wickets of the sluice are let down the fall is very slight; and it is almost nothing when the wickets of the weir and the trestles of the two bridges are dropped on the floor.

Finally, wicket-dams have this advantage, that a sheet of water of considerable depth, and as long as the dam, may flow without injury over the top; besides, the flutter-valves increase the discharge that the dam may give while it still remains closed. It is well to recall on this subject that one of the principal advantages of wicket-dams is that it is not necessary to connect with them the long-fixed weirs, which it is indispensable to attach to needle-dams, in order that when a sudden flood comes, there may be enough time to remove the needles and let down the trestles before the flood rises over the service-bridge.

In wicket-dams the overflow takes place over the dam itself without any inconvenience; and if there is a delay in throwing down the wickets, they swing spontaneously; in any cases the upper pool never rises to an immoderate height, and it is always possible to open the dam, which could not be done with a needle-dam were its bridge submerged. Floating ice in large quantities may even come without much inconvenience against the up-stream side of a wicket-dam, and pass over the top, as happened in 1870 and 1871 at Port-à-l'Anglais.

If we only consider the expense per running-foot, wicket-dams are perhaps more costly than needle-dams; but they are, on the contrary, much cheaper, if we consider the saving that results from suppressing the fixed weirs; and this is the chief cause for the adoption in Belgium of M. Chanoine's system for the dams on the Meuse.

CHAPTER VII.

POSSIBLE EXTENSION OF THE CONSTRUCTION OF WICKET-DAMS.

It was not without some apprehension that I undertook the study of the plan for the high wickets of the new pass at Port-à-l'Anglais, when its preparation was ordered on the proposition of Chief Engineer Cambuzat, by the ministerial decision of May 12, 1869, which approved the plan for deepening the lock; but experience has shown that the fears then felt were groundless, and that movable wicket-dams can be applied without difficulty to very great lifts, as the inventor of their machinery said from the first. It is true that the dimensions of some parts of the wickets of the Port-à-l'Anglais sluice have seemed to a few of the engineers who have visited it to be exaggerated; but I think that a very high dam cannot be made too solid, if we would avoid in the future great difficulties and heavy expenses in maintenance.

All the parts by which the closing is effected are maneuvered successively and separately, and this is done by means of windlasses, to which the necessary power can always be applied, whether they are carried on a boat or on a service-bridge; hence, the maneuvers are always possible, and are even easy, if the various parts of the structure have been suitably calculated. From the experience of the Port-à-l'Anglais dam, I am convinced that it would be easy to build dams on the same system to form pools having a depth of 14.75 feet over the sill of the navigable pass, and even more.

It has been shown above that the Port-à-l'Anglais dam is better arranged now than before, as it is divided into three sections, the sills of which are set at different levels. The necessity of dividing movable dams into several parts, to facilitate maneuvering, cannot, in my opinion, be too strongly insisted on. The study of the water-way to be given to the different passes and of the levels at which their sills are to be placed is, to my mind, the main part of the plan for a dam. It seems to me to be much more important than the consideration and choice of the machinery for closing; and if the mode of closing depends to a certain extent on this choice, we can almost say that it is relatively a matter of little moment, and that any of the systems may be adopted, and may work well, if the water-ways of the passes and the levels of the sills be so arranged that all the maneuvers can be performed with but a slight fall.

The path is now well marked; every day sees some improvement in the machinery in use; new devices are invented without difficulty; and, before long, engineers will only be troubled in choosing between them, or, at least, they will only have to make their choice according to the conditions of the problem to be solved. For example, as matters now stand, the height of 10 feet above the sill seems to be a limit that cannot yet be passed by dams with trestles and needles, as is shown by the experience at the dams established on the Lower Seine at Suresnes, Martot, &c. The experience gained at the new Port-à-l'Anglais sluice seems to me, on the other hand, to prove that the height beyond which Chanoine wickets can no longer be maneuvered is far from being attained with a pool of 13 feet in depth at the sill, and the limit of application of this system is yet unknown.

For a dam intended to form a pool 14.75 feet deep at the sill of the navigable pass, three sections, separated by two piers, as at Port à-l'Anglais, would probably not be sufficient, and it would be necessary to divide the floor into four parts, set at different levels.

The length of the navigable pass, closed by wickets, 14.75 feet high, with a sill 2 feet or 2.3 feet below low water, having been determined by the necessities of navigation, the second section designed to insure the discharge of the river at its average stage without causing any injurious fall, could not have its sill much above low water, and consequently would be closed by wickets about 11½ feet in height; the sill of the weir, whose length would be fixed by studying the floods, might be placed about 3.3 feet above low water, and could be closed by wickets of about 8.25 feet high. But, under these circumstances, it would not be easy, after closing the dam, to regulate the level of the pool, and it would undoubtedly be necessary to divide the weir into two parts, one of which should have its sill at 5 or at most 6½ feet below the surface of the pool.

It is not solely to facilitate closing, and to diminish the first cost, that it is necessary to divide the dam into several sections, the sills of which are placed at different levels, but also to prevent the maneuvers from causing too sudden changes in the regimen of the river. The surface-slope above a dam, whose calculation has frequently been attempted with no great success by means of formulas for backwater more or less hypothetical or empirical, varies within very wide limits according to the discharge of the river. At the same dam, the slope of the upper pool may be almost nothing when the discharge is a minimum, and the pool at its greatest height; while, on the contrary, it approaches the natural slope of the river when the water is in sufficient abundance to obliterate the fall of the dam when it is submerged or partly opened.

The inaccuracy of the various formulas that have been proposed for calculating the backwater on the up-stream side of a dam proceeds from the fact that they do not take sufficient account of the discharge of the river, which, under ordinary circumstances, has only an indirect influence on their terms.

This variableness in the slope of the pools demands, to my mind, an arrangement for gradually opening the dams as the discharge increases, and for closing them in a similar manner under the opposite circumstances; in other words, the lift of a dam and its water-way should vary greatly with the discharge of the river. I think that it is not immediately above the dam that the level of the water should be kept constant, but on the lower miter-sill of the lock at the head of the pool, or rather over the most important shoal in this pool, if we do not wish to cause at certain times sudden changes in the regimen of the river and in the mode of navigation. When there is a large number of dams placed successively, as on the Upper Seine and the Yonne, we are necessarily obliged to maneuver them all very nearly at the same time when the water falls to a certain fixed level, or on the coming of a flood. These simultaneous maneuvers then cause a great disturbance, which stops navigation for several days, and changes the most quiet river into a torrent, whose floods and ebbs extend down-stream with excessive rapidity.

A dam ought, then, to be so arranged that its lift will have been already considerably reduced when the time comes for opening it, and so that its lift may be gradually increased when it becomes necessary to close it.

Viewed in this light, needle-dams have somewhat of an advantage over wicket-dams, because they permit the fall to be regulated at will by separating or closing in the needles, provided that they can be easily handled and are not too long; in wicket-dams, on the contrary, all the wickets of a section are, as a rule, lowered at once by the tripping-rod, although that is not absolutely necessary. But, be the system adopted what it may, any dam whose sill is at the same level all the way across the river would, I think, be very badly arranged, not only as regards cost of construction, but also as to the facility of maneuvering it, and of regulating the level of the pool, and the variations in the regimen or the river.

To return to the supposition of a dam that would secure during low water a depth of 14 feet 9 inches over the sill of the navigable pass; this depth should be much reduced during average stages in proportion as the discharge of the river and the slope of the pool increase. In this view, the weir should be quite long; and we have seen that it would be well to divide it into two parts, in order to reduce the cost of construction and to facilitate handling.

The two parts of this weir might be built with advantage and economy on M. Poirée's system. We must not forget, however, that this would present the disadvantage of diminishing the length of the overflow, which takes place over the top of the wickets, and that, consequently, the length of the other sections, over which the water might fall, should then be sufficient to take the place of a permanent weir.

Besides this, we would lose the advantage of automobility within suitable limits now enjoyed by the Port-à-l'Anglais weir, thanks to the Chanoine wickets and the service-bridge. In fact, if we connect the wickets of this weir with the service-bridge by suitable chains, and a flood should come, they slope spontaneously to 30°, 40°, 50°, according to the amount of slack left in the chase-chains, until the latter are taut; if, then, the waters fall, the wickets rise of themselves with a rapidity inversely proportional to the amount of inclination.

It even appears to be possible to allow the wickets to lean much more, and still to have them come up spontaneously, after a very slight lowering of the surface of the pool, by placing small flutter-valves in the chase; for this expedient seems to have been successfully tried in the dams on the Meuse, near Namur, by MM. Dumont and Hans, engineers of the *ponts et chaussées*, in Belgium.

To preserve this advantage, the part of the weir whose sill is lowest might be arranged in this manner, while that part whose sill is higher might be built on the system of M. Louiche-Desfontaines.

But trestles and needles might also be adopted for the entire weir, and the water-way might in some cases be increased by placing flutter-valves in all the wickets of the other two sections, arranging them so as to open spontaneously at a given level of the pool. The lock-tender should then close these small valves by hand at the proper time; but the spontaneous righting of some of them might also be secured by limiting their inclination, either by small chains fastened to the wickets, or by springs, as Chief Engineer Krantz has thought of doing, he being the first to whom the idea presented itself of putting small automatic wickets in the large shutters of a dam. He gave the name of flutter-valve (*papillon*) to these little contrivances, which M. Dumont then tried in the weirs of the Meuse, and which I have since applied to the navigable passes of the Seine.

As to the dam, properly so called, the height of which above the sill would be about 11½ feet, it would probably be very difficult, if not practically impossible, to close it with needles, and, furthermore, it would be well in this case to avoid the use of trestles, in order to provide against the sudden arrival of floating ice, as happened two years in succession at Port-à-l'Anglais. Wickets similar to those of the sluice of the dam just mentioned would answer perfectly well to close this pass, and the experience gained at Port-à-l'Anglais shows that wickets of about 11½ feet in height can easily be raised by a maneuvering-boat, provided that during the work a sufficient water-way be left to the river, so as to prevent the formation of much of a fall before the operation is ended.

The wickets of the navigable pass should then remain swung during the closing of the higher pass, which would require above the wickets a service-bridge of 14 feet 9 inches in height. Moreover, this structure would probably be indispensable for maneuvering such large shutters. The construction of the trestle for this service-bridge would present no difficulties. As to the wickets themselves, very few changes would be required in the model adopted at Port-à-l'Anglais.

It would undoubtedly be sufficient to increase very slightly the dimensions of the various parts of the model, and particularly the horses, which should be provided with a Saint Andrew's cross; but it would be well, I think, to change the floor entirely, and to follow the mode of construction used on M. Chanoine's weirs, which are set on a timber grillage bedded in a mass of béton, which is covered by a simple paving.

But in this grillage cast-iron should be substituted for wood. A cast-iron beam, placed parallel to the current in the axis of each wicket and corresponding trestle, should support the journal-boxes of the latter, and the heurters and slides of the wicket; it would resist the upward pull on the sill, which would no longer require to be anchored deeply in the masonry of the floor. Stringers placed under the sill of the trestles, and under that of the wickets, and under the tripping-rod, would support the lower journal-boxes of the wickets and of the trestles, and also the supports of the tripping-rod, and would insure the proper spaces between the various parts of the machinery; they should be provided with wooden cushions to deaden all shocks.

With this mode of construction, the floor might be made of a simple mass of béton covered with a pavement between the cast-iron beams and stringers; the saving on the cut stone would in part make up for the expense of the cast-iron grillage, the importance of which would, moreover, be justified by the dimensions of the dam and the result to be obtained. Finally, all parts of the machinery might be adjusted and tested at the shops before being taken to the works; we would then be certain beforehand of the proper construction of all the joints and bearings; there would be no fears of misfits just as they were being placed on the floor, and the facility with which this could be done would greatly diminish the duration of the works, and consequently the cost of pumping.

In several memoirs published in the *Annales* endeavors have been made to compare the merits and defects of the various systems of movable dams, and sometimes one has been considered better, sometimes another; but, far from entering into competition, these different inventions complete each other, and in almost every system some portion of its predecessors has been utilized; besides, each one has its special advantages, and the choice to be made between them depends upon circumstances, and upon the result to be obtained. M. Cambuzat has stated, in his recent article on the navigation of the Yonne and the Seine, under what circumstances, according to the experience acquired in this navigation, the dams of M. Chanoine or those of M. Poirée should be preferred; it depends principally upon the depth of the pool at the sill, since the maximum height to be obtained by needles is nearly reached at the dams of Martot, Suresnes, and others; while the limit of swinging-wickets has not yet been reached at Port-à-l'Anglais. Besides, we have just seen that, for a dam of great height and length, it appears reasonable to employ at the same time different appliances, which, placed near each other, would tend each to complete the other, while striving for the same end.

CHAPTER VIII.

THE USEFULNESS AND THE FUTURE OF MOVABLE DAMS WITH HIGH LIFTS.

It is the more important to show the usefulness of movable dams of great height, inasmuch as the invention of these dams is essentially French, and wholly due to engineers of the *ponts et chaussées*, among whom it is sufficient to mention MM. Poirée, Thénard, Mesnager, Louiche-Desfontaines, Chanoine, and also M. Carro, who published in 1870 the plan for a new system of dams, and M. Krantz, whose recent invention is now on trial at Bougival.

The problem to be solved in improving rivers by means of dams consists in maneuvering gates of greater or less dimensions under a fall of water. The solution is very difficult with small means and small machinery. So long as efforts were made to avoid the use of windlasses, and to be content with man-power, the dimensions of the implements for closing had to be reduced to those of horizontal beams or vertical needles; as has been the case from time immemorial for the passes of the Upper Yonne, which are closed by dams, with beams or with ropes and needles; or else, as M. Poirée did, the height of the needles was increased, and they were supported on trestles; afterward, when windlasses were adopted, in order to save the expense of a bridge, the windlass was placed on a maneuvering-boat, as was done by M. Chanoine after experimenting at Courbeton with Thénard shutters maneuvered from the top of a Poirée bridge; or else an effort was made to use for the maneuvers the hydraulic force of the river itself, by making it act with a small head on a large surface, as at the dam at the bridge across the Neuville, the gates of which are an imitation of the American lock-gates with horizontal axes, and as was afterward done by Louiche-Desfontaines, by M. Krantz, and by M. Carro, in the plan which he published in 1870; or, lastly, a strong hydraulic pressure was made to act on a piston of small area, as M. Girard put into practice at the dam at Île Brûlée, near Auxerre.

But the difficulty becomes much less when we seek to obtain a more important result, which will warrant a greater outlay, and when we no longer recoil from constructing a service-bridge carrying a crane. When still greater lifts are to be obtained, all that will be needed will be to replace the movable service bridge by a large stationary bridge, from the top of which it will be always easy to handle the gates with a crane of sufficient power, as Engineer Frimot proposed in 1827, to give a great draught of water in the Seine between Paris and Rouen.

The dam of La Monnaie, across the left channel of the Seine at Paris, partly realizes this idea, with this difference, that the bridge is replaced by a row of piers too near together for the purposes of navigation. This trouble would be avoided with an actual bridge, which would at the same time establish communication between the shores; the bridge over the sluice at Belombre on the Yonne, and that over the sluice at Arcis on the Cure, already furnish examples.

Inland navigation is daily demanding a greater depth of water; on this depends its future; the example of the Lower Seine proves it conclusively, since successive efforts have been made to give a draught of 4 feet, then 5¼ feet, then 6½ feet, and now it is proposed to carry it up to about 10 feet. It would be well to remark in this connection that wicket-dams offer this advantage over others, that it is not very difficult to increase their height within certain limits, when, after they are built, we desire to increase the depth of their pools. We have already seen how easy it would be to increase the draught of water in the Port-à-l'Anglais pool from 5¼ feet to 6½.

Very high movable dams can alone insure great draught of water for a river; thus we could scarcely obtain a draught of 9 feet 10 inches with dams of 13 feet 1 inch in height, except by placing their sills at the low-water level, or even above, which would present the double disadvantage of requiring an entire cessation of navigation for the slightest repairs to the lock, and of causing a permanent fall over the sill, even when the dam is open. However, the navigable pass might, perhaps, be abolished and replaced by a second lock. Deep pools are likewise indispensable for improving rivers of steep slope, unless locks be multiplied beyond all reason. Objections have been made, to be sure, to the construction of movable dams on rivers with steep slopes, because, as a rule, these rivers bring down sand and gravel that would form deposits over the machinery during floods. But sand could scarcely form a deposit at one time all the way across a river; hence it would probably be sufficient, to prevent it from interfering with the maneuvers of a dam, to divide the latter into several sections, and to close the unobstructed passes so as to clear out the others by the current that would result. Besides, experience seems to have already refuted this objection; for the slope of the Upper Yonne is great, and there are also movable dams on the Loire at Roanne and at Decize, and on the Allier at Vichy.

Another objection has been made to very high dams, and that is that their pools would submerge the low portions of the valley; but, in the generality of cases, the shores of pools can be diked, and the water leaking through can be caught in a lateral ditch and emptied below the dam.

It will be seen, by a recent article from M. Cambuzat, that this method has been successfully adopted on the Yonne.

Far from this being any inconvenience in principle, it would, on the contrary, be an advantage to agriculture to raise the pools a little above the level of the valley, so as to employ the water of the river for irrigation. But the construction of dams on rivers is not alone useful to commerce as regards water-transportation, and to agriculture as regards irrigation. I think that the time has come to utilize the fall of rivers and navigable streams, as has just been done for the Rhone, at Bellegarde, at a considerable cost for first establishment, (*Annales*, 2d half-year, 1872, p. 371,) and as had already been done on the Marne, at Saint Maur, Trilbardou, and Condé-sur-Marne. Large movable dams allow the interests of navigation to be reconciled with this improvement, which the steady rise in the price of coal will probably cause to be realized everywhere at no very distant day.

The discharge of the Seine at Port-à l'Anglais is but little less than 1,400 cubic feet; and if only half be used for running a factory, (for I am persuaded that we shall be able to reduce the loss of water through the dam as much as we desire, when that becomes necessary,) we shall obtain, with a fall of 9.84 feet, a disposable power of 800 horses, the annual rental of which, allowing for stoppages caused by high water, may be estimated at about 200 francs, ($37.20,) (*Annales*, 2d half-year, 1872, p. 375,) or a total of 160,000 francs, ($29,760.)

A steam-engine of 800 horse-power consumes not less than 40 to 50 tons of coal a day; judging by this, the Port-à-l'Anglaise dam is the equivalent of a coal-mine yielding from 15,000 to 18,000 tons of fuel per annum.

We have seen in the recent article by M. Cambuzat, that the cost of slackwatering the Seine from Paris to Montereau is only one-hundredth of a franc per ton per kilometer, (0.621 mile,) or a little less than three mills per ton per mile for the present traffic; but, far from being onerous, the construction of dams might become productive, since the fall of the Port-à-l'Anglais dam might furnish a revenue of about 10 per cent. of the capital employed in its construction. It seems to me extraordinary that none of the falls formed by the dams of the Seine and the Yonne have yet been utilized for manufacturing purposes. The stoppages to which the factories located at these points would be exposed are perhaps the cause. But these stoppages, during floods, will be shorter and less frequent as the pools of the dams are deeper, and to my mind this is one more reason for increasing the height of the dams.

PARIS, *May* 15, 1873.

ADDITIONAL NOTE.

ON THE AUTOMATIC WICKETS OF THE WEIRS ON THE UPPER SEINE.

MM. Chanoine and de Lagrené, in their first article on wicket-dams, say, in speaking of the automatic wickets of the weirs:

> * * * * The wickets that are swung, as we have mentioned, under an overflow, varying from three to ten inches, according to the dams, will rise spontaneously when the up-stream level shall have fallen to 5¼ inches below the crest of the dam, *if the counterweights be fastened on the breech.*
>
> The preceding calculations are only approximate, and it is difficult to make them exact before making new experiments, in order to determine quantities that we do not know with certainty. * * * (*Annales*, 1861, 2d half-year, p. 311.)

Thus, they supposed, from approximate calculations, that the wickets would swing under an overflow of from three to ten inches, and all experiments confirm this result; but they also supposed that these wickets would right themselves spontaneously when the surface of the pool should fall to 5½ inches below the crest of the dam, and this is what experience has not confirmed. Furthermore, they hastened to add that this calculation was only approximate, and should be verified by experience.

FIRST EXPERIMENTS.

As soon as the dams on the Seine were completed, experiments were made to verify the approximate results of the calculations that we have just mentioned, and M. de Lagrené gives an account of these experiments in a report dated June 23, 1865. The first experiments were made December 8, 1864, at the Albon dam, and on the 12th of the same month at the Port-à-l'Anglais dam; the wickets swung under the influence of an overflow of 5½ inches in the first case, and of 4 inches in the second, but they did not right themselves until after a fall in the pool of 3.3 feet and 3.9 feet below the normal level, although movable counterpoises were attached to the breech. The inclination of the wickets when swung was 15° below the horizon.

Steps were immediately taken to insure the righting of the weirs without allowing the surface of the pool to fall so low, and various means were tried to accomplish this righting by hand. For example, use was made of the maneuvering-boat resting against the wickets that remained standing, when a fall of 1 foot to 1.3 feet in the pool insured the stability of these wickets; or, for a smaller fall, this same boat was fastened to anchors, or to piles driven in the river. Experiments were made with the wooden screen in use at Melun for righting the last wickets of the navigable pass of this dam; but this screen, which insures the spontaneous righting of the wickets of the navigable pass so soon as it is placed vertically against the breech, has but a very slight influence on the weir-wickets, whose breech is shorter. All these methods were attended with some inconvenience, and were dangerous to the lock-tenders.

WICKETS WITH A LIMITED INCLINATION.

To avoid these troubles, an endeavor was made to hasten the spontaneous righting of the wickets by limiting, in various ways, the angle through which they could swing. Experiments were made on the 22d of May and 1st of June, 1865, at the Citanguette dam, in order to study at the same time the influence of the angle of inclination of the wickets when swung, and that of the supplementary counterpoises fastened to the breech.

It was noticed that the counterpoises fastened on the breech were almost without effect at the moment when the swing took place, and also when the wickets righted, on account of the shortness of the lever-arm of the counterpoises; but that the angle of inclination of the wickets exerted a considerable influence on their spontaneous righting.

The following table, taken from the aforementioned report, June 23, 1865, and reproduced in the article of MM. Chanoine and de Lagrené, of March 21, 1866, (*Annales*, October, 1868, p. 441,) gives the result of the experiments:

Angle of the wicket above the horizontal.	Fall of the surface of the pool below its normal level, at the instant of spontaneous righting.	Remarks.
	Feet.	
+ 10°	2. 62	Each time that the wickets righted spontaneously, the depth of the overflow was about 2 inches.
+ 15°	2. 30	
+ 20°	2. 13	
+ 25°	1. 80	
+ 30°	1. 48	
+ 35°	1. 15	
+ 40°	0. 82	
+ 45°	0. 66	

REGULATING-CHAINS.

These experiments seeming to be conclusive, M. de Lagrené presented, on the 22d of June, 1865, at the same time as the aforementioned report, a plan for regulating-chains intended to limit the angle of inclination of some of the wickets of each weir, to insure their righting spontaneously after the passage of small floods.

This plan, whose arrangements and drawings were given in the *Annales des ponts et chaussées*, (October, 1868,) was approved by a ministerial decision of August 24, 1865, in these words:

> I authorize you to make the experiment you propose on one of the dams on the Seine. I request the inspector-general to report to me on the subject, after he has informed himself of the result of this trial.

The new experiments ordered by this decision were made on the 23d, 26th, and 30th of September, and the 24th of October, 1865. They confirmed the results recorded in the above table, save the variation of a few hundredths of a foot more or less, according to the wickets experimented on; for a very slight difference in the construction of a wicket, and particularly in the position of its axis of rotation, is sufficient to make it more or less sensitive.

Inspectors-General de Breville and de Sermet were present at the experiments of the 30th of September, and M. de Sermet made the report on them to the administration.

Finally, by a decision of December 4, 1866, the definite plan for regulating-chains was approved. This decision reads:

> The explanations given in the reports annexed to the project for maneuvering these wickets show that, by fastening chains to twenty of the wickets of a dam, its regular working would be secured.
>
> In accordance with the opinion expressed by the council of the *ponts et chaussées* I approve the project presented on the 22d of November, 1865, by Engineer de Lagrené, for chaining-apparatus intended to complete the automobility of the wickets of weirs, and I authorize the application of this apparatus to twenty wickets of each of these weirs.

NUMBER OF CHAINED WICKETS.

In the report of June 23, 1865, and in the article of March 21, 1866, (*Annales*, October, 1868, pp. 435–442,) M. de Lagrené explained very clearly why it was proposed to apply chains to only fifteen or twenty wickets of each weir.

We read in the last memoir, (page 437:)

> This simultaneous swinging of a large number of wickets ought not to take place, because the wickets, although constructed after the same pattern, are not equally sensitive. * * * * When the water pours over a weir whose wickets are up, all the wickets are on the point of swinging, but only one or two actually do so. If, in spite of this opening, the water continues to rise, one or two other wickets swing, and so on, until the water-way is sufficient for the discharge.

(Page 438:)

> Experience must decide this question. We understand that in some exceptional cases such a mass of water may come down suddenly as to cause all the wickets to swing at the same time.

(Page 442:)

> It is sufficient to apply chains to fifteen or twenty wickets of each weir, taking care to select the most sensitive, or rather to make them more sensitive by lengthening the chase, so that they may always swing first, and the others will be left free to swing fully, so as to allow the passage of floods that may arrive suddenly.

And further on:

> Experience must determine for each weir the number of wickets to be fitted with chains.

In addition, in the report of June 23, 1865, we read:

> If all the wickets of a weir were so arranged as to swing within a limited angle, difficulties might arise; should a sudden and unforeseen flood come, the water-way of the weir would then be more or less contracted.

And further on:

> We think that fifteen wickets will always be enough, because, when the dam is raised, the discharge of the Seine is less than 6,340 cubic feet per second. Finally, it is a question that experience will decide.

Lastly, in the article of March 21, 1866, M. de Lagrené is careful to add as a note to page 431:

> The construction of a bridge supported by trestles on the up-stream side of the weir * * * * would overcome all difficulties and all objections except a slight increase of cost.

This solution had already been pointed out in an article of December 31, 1866, (*Annales*, March and April, 1866, p. 210.)

PLACING THE REGULATING-CHAINS.

The final plan for regulating-chains, limiting the inclination of the wickets, had been approved for twenty wickets at each weir by the decision of December 4, 1866, and funds were furnished in 1867 for the execution of this work on the dams of the department of the Seine-et-Oise and of the Seine; consequently, regulating-chains were added to twenty wickets of each of the dams of Port-à-l'Anglais, Ablon, Evry, and Le Coudray during the months of October and November, 1867.

These regulating-chains were placed on the twenty adjoining wickets situated in the middle of each weir, so that there were left fifteen free wickets on either side of the confined wickets. Furthermore, care was taken to enlarge the chases of the confined wickets by wooden strips of ¾ of an inch to 1⅛ inches, and likewise to enlarge the breeches of the free wickets, so that the latter would require a greater height of the water to swing them than the former. Experience has since shown that the confined wickets thus arranged swing first, and that an increase in height of water-surface of from 2 to 2½ inches was afterward needed to make the free wickets swing.

EXPERIMENTS OF 1868.

The above mentioned dams having been closed from the end of May to the first of November, 1868, it was easy to observe how they acted under various circumstances, and especially under the influence of very variable discharges and changes of level in the pools.

The following is the result of the observations which were made:

1. When the level of the pool rises above the normal level, the confined wickets swing first, and in succession; so that, if the discharge of the weir be small and slow, the opening given to the waters by some of these wickets suffices to lower the surface of the pool.

It has been observed at the four dams mentioned above that frequently two, three, five, ten, or even all the twenty confined wickets would swing to the angle allowed by the regulating-chains without any free wickets swinging.

2. The confined wickets swing as soon as the water overflows to a depth of from 4 to 6 inches.

3. When the increase in the discharge of the river is such that the water-way furnished by twenty wickets at an angle of 45° is not sufficient to prevent the surface of the pool from continuing to rise, the free wickets in their turn swing successively.

It has been several times observed that, in consequence of the swinging of the wickets of weirs further up stream, which were not furnished with regulating-chains, there resulted so great and so rapid an increase in the discharge that half an hour after the opening of the twenty confined wickets the thirty free ones were all swung.

4. The overflow necessary to swing the free wickets was from 6 to 8 inches, becoming less as the level of the lower pool rose in consequence of the opening of the confined wickets.

5. The confined wickets right themselves spontaneously after a slight depression of the pool, as is shown in the above table of angles of inclination. The wickets of the four dams nearest to Paris generally right themselves after a lowering of the surface of from 6 to 8 inches. The angle of inclination of these wickets was about 45°, but was not measured exactly.

6. The free wickets were always righted by hand without waiting for

their spontaneous righting, which would have required too great a lowering of the surface of the pool. But, as this operation required the use of the maneuvering-boat in a very swift current, it generally could not be performed except after too great a lowering of the pool. Besides, it is often dangerous, and it is almost impassable at night.

7. When the navigable passes were opened on the first of November, the confined wickets and a few of the free ones were swung; the opening of the pass having lowered the pool, the confined wickets immediately righted themselves, and it was easy to detatch their chains, and then to lay them down on the floor.

For this operation to have been impossible, it would have been necessary that the level of the water should have remained at 6.56 feet above low water after the navigable pass was opened. This case might, to be sure, arise in the case of a swift and unforeseen flood like that of September, 1866.

CONCLUSION.

To sum up, the expectations that were formed from the plan of using regulating-chains for the wickets of weirs have been perfectly realized except on one point.

It was hoped that the opening offered to the waters by a certain number of wickets leaning at an angle of 45° would generally have been sufficient to carry off small floods, and that the free wickets would very rarely swing. In fact, that appeared to be probable; for, before the closing of the dams, the discharge of the Seine during low water, and even at medium stages, varied slightly and gradually. However, care was taken to state in the plan that more complete experiments *were necessary* to determine the number of wickets which it *would be advantageous* to supply with regulating-chains.

These experiments were very completely made between the months of June and November, 1868; and they showed that, under the influence of the complete swinging of a movable weir with *free* automatic wickets, the discharge of the river below the dam would undergo very great and very sudden changes. Before the closing of the dams, the change of the level in the waters of the Seine above Paris, under the influence of an artificial flood on the Yonne, averaged from 1.30 to 1.60 feet from day to day, and this variation only took place gradually. On the other hand, when a weir is entirely swung, the water below suddenly rises 5 feet, and sometimes more.

This having occurred several times in 1868, experience shows that it is not enough to confine a part of the wickets of the weir, but that it is necessary to confine them all. Now, this is not possible with the mode of attachment adopted for the chains, since, in some cases, if the inclination of 45° for a whole weir were not sufficient for the passage of a flood it would be impossible to increase the water-way *without opening the navigable pass.*

Hence we must conclude:

1. That all the wickets of each weir must be confined, and that there must be some way of diminishing or increasing their inclination according to the importance of the flood to be passed.
2. A point of attachment must be provided for the chain which is easily accessible in all weathers, and even at night, whatever be the height of the water.
3. We must be able to change the length of the chains, and consequently the inclination of the wickets, in all weathers, and even at night, so as to regulate at will the surface of the pool.

4. The service-bridge, already described in the reports quoted above, seems to be the only mode of completely solving the problem stated in the two preceding paragraphs.

5. Telegraphic communication between the dams appears, moreover, to be necessary, in order that the dam-tenders above may indicate in good season to those below the inclination they must give to the wickets of their weirs.

AUTOMATIC MOVABLE DAM.

M. GIRARD'S SYSTEM, WITH HYDRAULIC JACKS.

The kind of movable dam which forms the subject of this description, and which has just been applied to a dam on the Yonne, is due to the late M. Girard, a civil engineer, well known by his works and his researches in hydraulics.

M. Girard's plan dates from 1869; the first description of it is found in an essay that he had published by Gauthier-Villars, entitled "The raising of water, the water-supply of cities, and the distribution of power to dwellings," (*"Élévations d'eau, alimentation des villes, et distribution de force à domicile."*) M. Girard was then full of the possibility of utilizing the motive-power of large streams for the assistance of manufacturing industries, by placing at their disposal an absolutely inexhaustible source of power to replace coal, whose ever-increasing consumption forces us to consider the possibility of its becoming exhausted; and it was in order to make high dams on rivers that he devised the system of movable dams, which he calls, in his essay, *hydromotor*.

He presented a model of it to the administration, who, after it had been examined by the general council of the *ponts et chaussées*, decided to try it on one of the dams then being built on the Yonne, between Auxerre and Laroche, in the division of which Inspector-General Cambuzat was then chief engineer. (Decision of December 15, 1869.)

The dam selected was that of Île Brûlée at Auxerre, about a mile below the city. It comprises, as do all the dams on the Yonne, a large lock, a navigable pass, and a movable weir. It was decided to try the proposed system on the weir; and M. Girard at once presented a plan that was approved by the minister under date of June 23, 1870.

M. Girard proposed to do the work by contract; and as his bid was accepted, he began; but the unfortunate events of 1870 interrupted the works, and M. Girard did not have the satisfaction of resuming them. He was killed by a Prussian bullet during the sad times of the Commune, and his heirs transferred his contract to M. Callon, his assistant and friend, who has just finished it.

GENERAL ARRANGEMENTS.

The system comprises—

1. A series of large wooden shutters or wickets, (Fig. 112, Plate 20,) moving around a horizontal axis, that turns in a cast-iron hollow quoin, (Fig. 113,) embedded in the crest of a masonry floor, (Fig. 114.)

2. Hydraulic jacks, intended to work each large shutter, fastened on the down-stream slope of the floor, and solidly anchored in the masonry, (Fig. 114.) The piston of each of these jacks carries a cast-iron transom, called the "piston cross-head," (*traverse tête de piston*, Fig. 110,) having the shape of a solid of equal resistance, which is guided in its course by three cast-iron slides (Fig. 111) on which it rests, (Fig. 110.)

The piston cross-head has three connecting-rods, (Fig. 110,) which are jointed to another cast-iron transom, or cross-head, that is movable in a hollow quoin, (*gorge de rotation*, Fig. 112,) fastened at the middle of the large shutters.

3. A set of copper-pipes, (*a*, Figs. 114 and 116,) which put each jack in communication with the generators, and accumulators, which are intended to send the water-pressure into the hydraulic jacks.

4. A water-power engine, constructed on the abutment of the weir, (Plate 20, Figs. 123, 124.) This engine consists of a turbine having a vertical axis, (Figs. 115 and 123,) of a double-acting water-pump, and an air-pump, (which are put in motion by the turbine,) and of an air-chamber of compressed air.

The pumps and the air-chamber or accumulator communicate with each other and with the jack by means of three-way cocks, (Figs. 117 and 118, which allow the water to flow either into the jacks, or into the accumulator, or to empty into a discharge-pipe.

The maneuvering of the shutters is accomplished by merely turning the cocks. By putting each jack into communication, either with the pumps or with the accumulator, the piston is made to run out, and the shutter to rise; on the other hand, by opening the cock into the discharge-pipe, the water runs out, under the pressure from the shutter, the barrel is emptied, the piston runs in, and the shutter falls down.

The accumulator is a governor for the action of the pumps; it also allows the dam to be raised before the water is backed up, and while the difference of level is insufficient to set the turbine in motion.

PRINCIPAL DIMENSIONS.

The weir of the Île Brûlée dam is 82 feet long; the sill is 6.56 feet below the level of the upper pool; the fall is 6 feet.

There are seven shutters; they are 11.55 feet broad and 6.46 feet high, from the axis of rotation to the top. When raised, they have an inclination of 4 base to 10 vertical; when down, they lie horizontally on the floor.

They are made of fir joists 4 inches thick, (Figs. 112, 113,) fastened at one end to the lower axle, and connected together at the middle by the piece of cast iron in which turns the cross-head of the connecting-rods, (Fig. 112.)

The jacks, like the shutters, are seven in number. They are made of cast iron. Their exterior diameter is 16 inches, and the thickness of their walls is 1½ inches. They are anchored into the masonry by two strong wrought-iron rods, running through the entire mass, (Fig. 114,) and bolted to two strong ears, cast on the barrel of each jack.

The piston is of cast iron, covered with a jacket of red copper; its diameter is one foot. It slides through a stuffing-box of hammered copper, which forms a joint that becomes tighter as the pressure increases.

The supply-pipes *a* (Fig. 114) enter the barrels of the jacks at the bottom; they are of copper, and are 1 inch in diameter. They are set in a trough cut in the floor, which terminates at the distributing-cocks in the engine-room, (Fig. 116.) Each jack has a separate pipe.

To be protected from frost, the jacks were put wholly below the surface of the lower pool. As this arrangement makes it difficult to inspect them, or to make repairs, masonry partitions, having a groove on each side, (Fig. 122,) were built between the jacks; and, by means of stop-planks placed in the grooves, temporary coffer-dams may be formed' and each compartment may be emptied by itself.

The turbine has a vertical axis, and is 4 feet in diameter. By means of its upper crank, *a a′* (Figs. 120 and 121,) it works a double-acting water-pump with a plunger, *p p′*, and an air pump, *r r′*, both being mounted on the same cast-iron bed-plate. The two pump-barrels are shown at *b b′*. The water is drawn up through the pipe *c*, and is discharged through *d d*.

One of the clack-valves is shown in section in Fig. 120; they are guided in their motion by a stem passing through a stuffing-box, and having a spring pressing on its head. The object of this arrangement is to force the valve to return to its seat so soon as the piston reaches the end of its stroke; by this means the shocks are avoided, which would certainly occur were the valves closed by the pressure of the water. The piston is of bronze, 3 inches in diameter, and its stroke is 6 inches.

The air-pump has but one barrel. The piston *g′* is fastened on the same rod as the piston of the water-pumps; air enters through the pipe *e*, and is discharged through *f f′*. Two ball-valves regulate the action of this pump; they can be thrown out of play at will by opening the cock *g′*.

h h′ is a small air-chamber, which serves to regulate the action of the water-pumps when the jacks are worked directly, and without the intervention of the accumulator.

The same figure shows the arrangement for oiling the turbine. The driving-shaft m^2, on which the turbine is keyed, is hollow. It turns about a stationary shaft of wrought iron, *n′*, on which its upper end is supported by means of a pointed pivot *k′*. An opening is made in the hollow shaft to pour oil into the cup in which this pivot stands.

The water-pumps draw directly from the river when the water is clear, or from a reservoir built in the abutment *a′*, (Fig. 123.)

The reservoir of compressed air is a cast-iron cylinder, (Fig. 119,) whose interior diameter is 26 inches, and whose height is 11½ feet. The walls are 2 inches thick.

The arrangement of the maneuvering-cocks is shown in Fig. 116. The pipe *d* connects the air-chamber with the distributing-pipe *b b′*, on which are placed the seven cocks belonging to the different jacks. The pipes *a* lead from the cocks to the jacks. The discharge takes place thróugh a pipe, *c c′*, which returns the water to the reservoir in the abutment.

Fig. 118 shows the cock which is attached to the discharge-pipe of the pumps, and which either permits us to make a communication between the pumps, the accumulator, and the jacks, (which is the position shown in the figure,) or else to act directly on the dam without the use of the accumulator, or, finally, to close everything.

The apparatus, which is furnished with a safety-valve and pressure-gauges, which could not be shown on the drawing, have all been tested under a pressure of 35 atmospheres.

Finally, the hydraulic machinery is made complete by a guard-gate, handled from the inside by means of gearing, for opening or closing the inlet-culvert, and by a grating intended to prevent the entrance of floating bodies.

MANEUVERING THE DAM.

The dam is maneuvered in the following manner: if the weir and the pass are entirely open, and the accumulator is empty, we must begin by making a fall, so as to set the turbine and the pump in motion. This fall is easily obtained by closing the pass, which is constructed on the Chanoine system, and which is closed by means of a maneuvering-boat. As soon as the water held back rises above the sill of the weir, (3.28 above that of the pass,) there is sufficient fall to start the turbine. The jacks can then be worked directly by the pumps, and they may be raised in succession by opening the proper distributing-cocks.

As the water-surface continues to rise, the resistance of each shutter to being raised increases rapidly, but the force of the fall increases at the same time, and the turbine is always in condition to force out water at an adequate pressure.

This pressure varies from 2 to 5 atmospheres, from a fall from 0 to the maximum fall of 6 feet; as an average, not more than ten minutes is required to raise the entire dam.

As a general rule, it is preferable to perform the maneuvers with the accumulator. If the accumulator be empty, as was supposed, we begin by working the air-pump, without running the water-pumps; the air is compressed in the accumulator until a pressure of 10 atmospheres is reached; this requires nearly an hour; then the air-pump, which is not constructed to sustain a greater pressure, is thrown out of work, and the water-pumps are got under way. In a few minutes, half of its volume of water is sent into the accumulator, which doubles the air-pressure and brings it up to 20 or 25 atmospheres.

In this condition of affairs, the accumulator is able, by itself, to raise the whole dam, if the fall be not more than from 1½ to 3 feet; each shutter may be raised in succession by placing the jack in communication with the reservoir; we can also raise all of them at once, by turning on all the distributing-cocks, and then opening the cock leading to the accumulator. All the shutters are thus raised with the greatest uniformity, and in less than half a minute.

When the fall is more than 3 feet, the accumulator cannot finish raising the shutters. The volume of water expended by each jack is 3 cubic feet, or 21 cubic feet for all seven. The entire volume of the accumulator being only 43 cubic feet, 21 cubic feet cannot be withdrawn without the pressure falling to 10 atmospheres, which is not sufficient to raise the last shutters. In this case, the pumps are kept at work during the maneuvèr, and it takes from five to six minutes to end the operation.

Pressure is rarely wanting in the accumulator; it is almost perfectly tight, and does not lose more than half an atmosphere in a day. Consequently, the operation of raising the dam can almost always be performed in from ten minutes to a quarter of an hour, including in this the loss of time necessary to make up the loss of pressure of preceding days.

The shutters are lowered with equal facility; it is only necessary to turn the distributing-cocks, so as to open them into the discharge-pipe; so that, under the pressure from the pool, and the weight of the apparatus, the pistons run in, and force out the water that filled the barrels of the jacks, which escapes through the discharge-pipe. To lower a shutter requires about two minutes.

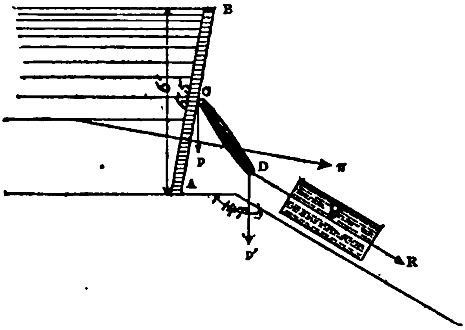
It is evident that the operations just described can be varied in many ways. The jacks being mutually independent, we can raise or lower the shutters in such order or in such numbers as may be desired; we can even raise one while lowering another. Finally, they can all be stopped at any point of their course.

To keep the shutters wholly or partly up, we have only to close the distributing-cocks. By reason of the incompressibility of water, the piston remains where it was stopped. However, the jacks are not perfectly tight, and the losses are shown by a slight lowering of the piston at the end of the day. There has been, so far, no great trouble from this; should the losses increase, a means of overcoming them will be shown further on.

CALCULATIONS AND EXPERIMENTS.

It was by graphic determinations, and by hypotheses on the shape of the sheet of flowing water, that M. Girard calculated the force necessary to raise the shutters in their various positions, under falls, varying from 0 to 6 feet. When the shutters are raised, the thrust R on the piston P is formed by the components in the direction D R of the weights p and p' of the apparatus at C and D, and the component in the same direction of the pressure π on the shutter caused by the pool above. p=2,244 pounds and p'=3,036. The shutter being 11.55 feet wide and 6.46 feet in height, π varies with the lift from 0 to 13,990 pounds, and the thrust R from 2,387 to 13,750 pounds.

Fig. 1.

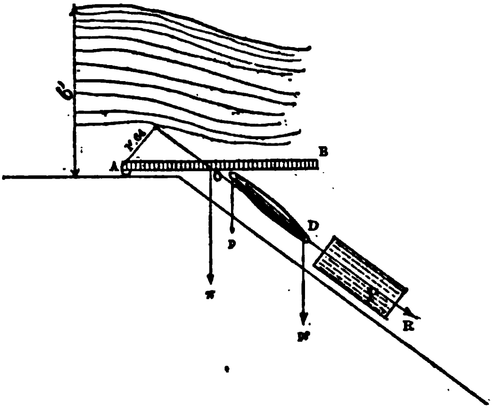


The surface of the piston containing 109.5 square inches, each atmosphere corresponds to a pressure of 1,610 pounds. The pressure, then, that forms an equilibrium with the thrust R varies from 1.5 to 8.5 atmospheres.

Experience very fully confirms these results of calculation, as was to be expected.

But there was less certainty of obtaining so exact a result for the case in which the shutter was down; the water would flow under a fall of 6 feet, in a sheet whose form was almost entirely unknown. M. Girard assumed that the pressure π would be equal in this case to the weight of a prism of water having the surface of the shutter for its base, and for its altitude half the height of the fall, which gave a maximum pressure, R = 25 atmospheres.

Fig. 2.



The pressure is certainly not reduced in the ratio of half the height of the fall, and we might fear that the shutters could not be raised without going very much beyond this pressure of 25 atmospheres, which had been given to the manufacturer as a maximum. But when the shutters are entirely down, their lower face is submerged, and we must calculate on an under-pressure, which would assist the raising. Experience has confirmed this anticipation, and the pressure scarcely reaches 15 atmospheres in the position of rest, and, as a rule, does not exceed 22 to 24 atmospheres during the ascending movement of the piston.

The increase of pressure during motion is due to the frictions, which are far from being constant, and vary with the conditions of the sliding surfaces. When the slides are muddy, and have not been used for some time, the friction may go as high as 5 to 10 atmospheres, according to the position of the shutter and the height of the fall.

It sometimes happens that, in consequence of the presence of a foreign body in the machinery or from other accidental cause, a shutter that has just been raised with 25 atmospheres requires 30 to raise it again, without the fall having been increased. There is no great trouble in going beyond the ordinary limit of 25 atmospheres, as the jacks have all been tested to 35. However, when this case arises, the accumulator, which, from containing compressed air, is the only thing liable to burst, is not used, and the jacks are worked directly by the pumps. It is true that some concussions are caused in the apparatus, and some shocks on the pump-valves; but, so far, these heavy pressures do not appear to have strained the machinery of the dam.

Fig. 112 shows a device that I placed for experiment on two of the large shutters, and which reduced considerably the pressure required to raise them. These two shutters have, near their top, flutter-valves, or small sheet-iron gates, turning about a horizontal axis, fastened to the rails of the shutter a little above one-third of their height, and prevented by a chain from inclining at a greater angle than 45°.

The working of these valves is easily understood: when the shutter is down, the valves open under the pressure of the water, and they lean almost in the direction of the fluid filaments; so that only their sheet-iron edge sustains a pressure. The resistance to raising the shutter is then perceptibly diminished, and, in fact, the pressure for these shutters is never more than from 15 to 18 atmospheres. When the shutters are raised, and the valves leave the water, they close themselves.

The valves, (of which there are three to a shutter,) 2 feet 11 inches wide by 2 feet 8 inches in height, have a second object, copied from what is done at other dams. It is to assist in regulating the depth of the pool by opening when the water rises, and closing when it falls.

TURBINE AND PUMPS.

The turbine is constructed on what is called the high-velocity system. It runs at the rate of about sixty revolutions a minute. Its yield in water pumped up varies from 0.30 to 0.45. Its average force is from 5 to 6 horse-power; but it can reach 12 to 14.

It is four feet in diameter, and the breadth of the movable crown is 2½ inches. The orifices, of which there are sixty, have each two inches of opening.

The diameter of the pump-pistons is 3 inches, and was calculated in such a way as to raise in ten minutes, with the mean velocity of the turbine, the water required to fill the barrels of the seven jacks.

The stroke is 6 inches, and the volume of water pumped up at each stroke is about 80 cubic inches, corresponding to a useful work of from 97 to 99 per cent.

The piston of the air-pump is 5½ inches in diameter; its stroke is 6 inches; the same as the water-pumps. The volume of air compressed at each stroke is more than 120 cubic inches. Care is taken to prevent this pump from becoming heated, by bringing in, through the supply-pipe, a small stream of water, which is forced into the accumulator with the air.

RESISTANCE OF THE MACHINERY.

The hydraulic jacks sustain no greater pressure than 1,414 pounds per square inch under a pressure of 25 atmospheres, and the accumulator not more than 2,404. The pressure on the copper pipes is 1,513 pounds.

The strains on the piston and connecting-rod, and on the connecting-rods themselves, do not exceed 2,830 pounds per square inch. The strains on the timbers of the shutters are less than 256 pounds per square inch.

The dimensions of all the machinery of the dam were so calculated that the strain on each one should be very much within the ordinary limits, whence results great safety in working the apparatus; and the only accident that has happened so far is the breaking of one of the slide-heurters, against which the end of the piston strikes, and by which its stroke is stopped. This heurter was broken in consequence of a defect in the casting, and the slide had to be replaced. The repairs were readily made in two days, thanks to the division of the dam into separate compartments, each of which can be emptied by itself.

Nevertheless, although all the machinery has been tested to 35 atmospheres, care is taken not to bring on the accumulator a pressure of more than 25 atmospheres. Even under this pressure it has been found difficult to prevent the escape of air through the joints and cocks. These leaks were specially noticeable when the works were new. The castings were not everywhere perfectly tight, and the air escaped principally through the upper cylinder-head.*

This escape could only be stopped by lining the interior with lead.

As to the other parts—pumps, jacks, and pipes—which contain water under pressure without air, they are tight enough, and the only losses are unimportant so long as the pressure is not greater than 25 atmospheres.

Beyond this, it is very difficult to prevent losses through the joints and cocks.

WEIGHT OF MACHINERY AND NET COST.

The following are the weights of the principal parts of the dam:

1.—*Jacks and shutters.*

	Pounds.
Barrel of jack, with packing and bolts	1,650.0
Cast-iron piston, with copper jacket	789.8
Piston cross-head, carrying three wrought-iron caps and three bronze plates	2,074.6
Cross-head at middle of shutter	596.2
Journal-box at middle of shutter	334.4
Lower journal-box and hollow quoin fastened to the floor	1,071.4
Slides	976.8
Wrought-iron connecting-rods, with bronze sockets	308.0
Bolts and various other pieces	506.0
Total for one shutter	8,307.2
And for six others of the same kind	49,843.2
	58,150.4

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* The loss of air was accompanied by a phenomenon that was interesting on account of its intensity, namely, the cold produced by the expansion of air. This cold was so great, that when the cylinder-head was unscrewed to introduce the lead it was found covered with a sheet of ice. Ice is also formed when a cock is open to let the air escape at a high pressure. This ice sometimes succeeds in entirely closing the mouth of the cock.

2.—*Turbine and guard-gate.*

	Pounds.
Turbine	576.4
Directrix	754.6
Socket and bolts	116.6
Hollow cast-iron shaft, with accessories	763.4
Stationary wrought-iron shaft	171.6
Guard-gate, with its accessories, machinery, grating, &c	2,699.4
	5,082.0

3.—*Pumps, machinery, and piping.*

	Pounds.
Pump-barrels and bed-plate	1,104.4
Valve-boxes, springs, &c	739.2
Supply-pipes	215.6
Accumulator	8,780.2
Bronze cock for the accumulator	8.8
Safety-valve, with weights and levers	50.6
Cast-iron discharge-pipe	111.0
Distributing-pipe	115.8
Red-copper pipes	884.4
Bands, bolts, and miscellaneous pieces	154.0
	12,200.0

Summary.

	Pounds.
Jacks and shutters	58,150.4
Turbine and guard-gate	5,082.0
Pumps, machinery, and pipes	12,200.0
Total	75,432.4

The whole, including the system of cocks, was furnished and put in place by contract at a cost of $8,600, (44,000 francs,) which makes the net cost about 11.5 cents per pound.

M. Girard, and after him M. Callon, had the sole charge of supplying and erecting the machinery, which was constructed at the factory of MM. Feray, at Essonnes. All of the exavations and of the masonry were at the cost of the government.

The masonry was put in by the contractor for the Île Brûlée dam; the amount required was not much greater than that needed for any other system of dams; and the additional expense for the small building in which the pumps are placed and for contingencies was only $1,150, (6,000 francs.)

The total expense thus amounts to $9,750, or $119 per running foot, including masonry.

SUMMARY AND CONCLUSIONS.

The Girard dam is remarkable for the rapidity and the ease with which it can be maneuvered, and it is really an interesting sight to see the large shutters rise against the current by merely turning a cock. It may, therefore, be said that the experiment just made at Île Brûlée is perfectly successful, and that so far everything has worked to a charm. However, the soundness of the objections that have been made, and that may yet be made, against this system of movable dams cannot be denied, in spite of its success.

In the first place, it is very complicated, although there are no very delicate parts. The jacks, the pumps, and the system of cocks form an exact-fitting machine, (*machine de précision*,) whose care will be very onerous and very obligatory.

Fouling with sand was apprehended. This danger seems to be groundless, by reason of the arrangement of the jacks and of their slides on the down-stream slope of the weir, which preserves them from any permanent covering of sand; but this would probably not be the case were the system applied to the passes, whose floor is at the level of the bottom of the bed of the river.

The most serious danger is from the effect of frost. In fact, it is necessary to remove all the machinery from its reach; and for this cause all the jacks were placed below the surface of the lower pool, at the risk of making repairs somewhat more difficult. The pumps, the accumulator, and the system of cocks are in a very tight building, which can be heated during the severe cold of winter. We can, therefore, hope that no accidents will happen; but the slightest carelessness will certainly cause great damage.

M. Girard had proposed, in order to guard against this danger, to use a mixture of water and alcohol, which might be kept in reserve in the masonry-cistern, which has since been used for a supply of pure water. The daily consumption of water being about 27 gallons, this method could not have been otherwise than very expensive, and it was not adopted.

Should it happen that the loss through the joints of the jacks, which is now scarcely perceptible, should increase to such a degree that a shutter should fall down or should become appreciably lowered during a single night, would it be possible to regulate the height of the pool so as to keep an amount of water sufficient for the needs of navigation? Here is a point still involved in doubt, and on which, up to the present time, there has been no chance of experimenting. However, the shutters can be kept closed, even if there are no leakages, by leaving them in communication with the accumulator; and, should it be necessary to retain them in any intermediate position it could be done by placing props under the piston cross-head, resting their feet against cast-iron heurters fastened to the floor. These props and heurters, which are similar to those of the Chanoine wickets, have not been put in place, but the cross-head and the masonry have been arranged so as to receive them, should a need for them ever arise.

The flutter-valves, which have been placed on two of the large shutters, and which could be easily applied to the remaining five, can be relied on to regulate the height of the pool.

The most serious objection that can be urged against this system is its extreme costliness. Undoubtedly, the net cost of $119 per running foot is much too high; and, if Île Brûlée weir had been more than 82 feet long, this price would have been much reduced. The price of 11½ cents per pound could also have been reduced, if the pumps and jacks could have been made by wholesale. Finally, the strength of the parts, and consequently their weight and cost, can be diminished by a general use of flutter-valves, or, better still, by employing M. Chanoine's plan and making the shutters movable, not above a fixed axis at the lower edge, but about the journal-boxes of a horse fastened to the shutters near the point of application of the water-pressure. But whatever course be taken, we shall always have a much more complicated system than either that of Chanoine or of Poirée, and one very much more costly:

The movable shutters of the Girard dam and their machinery cost per running foot	$119
The masonry, including coffer-dams and excavations, cost per running foot	60
Total cost per running foot	179

Now, the weirs of two other dams built just below Île Brûlée only cost from $55 to $60 per foot, all told. They are formed of a masonry floor of very nearly the same shape as that of the Girard dam, and limited in height to 6½ feet below the level of the upper pool. The dams are formed of a row of needles supported by Poirée trestles, and the attendants can maneuver them by hand.

If the management of these weirs is a little more troublesome than that of the Girard dam, the results are none the less satisfactory, and the depth of the pools can be exactly regulated, and with perfect safety.

The dams of the navigable passes constructed on the Chanoine system, with wickets 9 feet 10 inches high, seldom cost more than from $60 to $75 per foot.

To sum up, the net cost of the Girard system is, then, about three times that of the other two systems of movable dams, which have been built on the Yonne at the same time with it. In spite of its complete success, the trial made at Île Brûlée can only be regarded as an interesting experiment, but one which, to all appearances, will never be repeated except in special cases.

P 2.

IMPROVEMENT OF THE MONONGAHELA RIVER.

The work on this river consists in building a lock and dam at Hoard's Rock, W. Va., ninety-four miles above Pittsburgh and nine miles below Morgantown. Mr. S. Petitdidier, is the assistant engineer in charge.

The contract for the lock required that it should be finished by December 1, 1874. At this date the right or land wall was about half up, but nothing had been done on the left wall. The contractors applied for an extension, alleging, among other reasons, that they had been delayed in their operations by the illness of the engineer in charge. The only objection that could be urged against the extension was slowness, as the work done was excellent, and on my recommendation the Chief of Engineers authorized an extension until December 1, 1875.

By the end of the fiscal year the right or land wall had been finished, except a part of the coping. The foundations of the left wall were ready for the stone, of which several courses had been cut.

In this lock the method of filling has been changed from that indicated in the original plans. The latter were drawn with a view to filling the lock through the floor of the upper-gate chamber; but when the details were elaborated, I found so many practicable objections that I concluded to try another method which is somewhat more costly, but much more durable and satisfactory. The present plan is novel as far as I know, and contemplates building a well in each wall and connecting it with the upper pool by a short culvert opening into the gate-recess, and with the lock-chamber by a similar culvert directly under the upper culvert and opening into an arched space 7 feet in width, which connects with the lock-chamber by passing under the miter-wall. The advantages of the change are that the valve-gear is more simple, more accessible, and more easily repaired, and that the wooden floor of the gate-chamber, which is liable to constant leakage and requires frequent repairs, is entirely omitted. Perishable material is replaced by stone and iron, thus making a much more durable work. At the same time the lockage water enters the lock-chamber with equal quietness.

I had a careful comparison made of the relative costs of wooden and stone dams, and on my report the Chief of Engineers authorized the building of a stone dam by days' labor. The reasons which I urged when requesting this decision were that contractors seldom have money enough to push a work as rapidly as necessary, and that the completion of the dam was a delicate operation, requiring the utmost speed, and that in addition there were many operations around the lock, such as hanging the gates and wickets, building miter and lift walls, &c., that required special care and skill, and that it would be better to have all these operations progressing simultaneously under one head. The estimates show no difference in cost between a dam of wood and one of stone. This apparent anomaly is due to the smaller cross-section of the stone dam, and also to the ease with which excellent stone can be obtained in the neighborhood. Thus far operations on the dam have been limited to preparing the necessary material at the quarry. Work commenced in May, and to the end of June 200 cubic yards had been quarried.

If no unexpected contingency arises, the lock (except those parts necessarily postponed to await the completion of the dam) will probably be completed by the end of the year. The dam can be finished during 1876, so that the entire work will probably be ready for use by December, 1876. No further appropriation is needed for this lock or dam.

The lock and dam now under contract is the ninth of the Monongahela system, commencing at Pittsburgh. The six lower dams are the property of the Monongahela Navigation Company, and Nos. 7 and 8 are yet unbuilt. The Navigation Company are undoubtedly bound by law to build No. 7, and I understand that they are willing to do so. As fully explained in my previous reports, they could be required to build a dam high enough to back water up to the State line, but, for reasons mentioned in my last annual report, I think it would be better for the United States to build No. 8, below the mouth of Cheat River, and to only require the Navigation Company to put 6 feet in its lower miter-sill.

The following is the estimated cost of a stone lock at Laurel Run, about a mile below the foot of Cheat River ripple:

ESTIMATE FOR 1876–'77.

Mr. Petitdidier made a careful examination in June of this year to ascertain the best site for the lock and dam below the mouth of Cheat River. The most favorable site that he could find was about two miles below the mouth of Cheat, and just below Laurel Run. The reason for this is, that a careful examination of the bottom of the river below Point Marion showed that the depth of sand and gravel was so great as to make it impracticable to build a lock and dam except at very great cost. Rock was not found within reasonable distance of the surface until he arrived at Laurel Run, where the average depth to rock is 5 feet. The stratification of this neighborhood is well known, as it is a small oil center, (Dunkard's Creek oil district,) and wells have been sunk at many places below Point Marion. The well-diggers report about 30 feet of quicksand over the rock. The necessity of selecting Laurel Run as the place for the new lock is therefore very apparent.

The facilities for obtaining stone near Laurel Run cannot be told until quarries are opened; but there is reason to believe that it will cost more than at Hoard's Rocks, and therefore larger prices have been used in the estimates.

The lock will be of the same size as that at Hoard's Rocks, and the same profile will be used for the dam.

LOCK AT LAUREL RUN.

Earth excavation, 4,167 cubic yards, at $1	$4,167
Rock excavation, 2,500 cubic yards, at $2	5,000
Foundation masonry of uncoursed rubble, 2,075 cubic yards, at $7	14,525
Uncoursed rubble above foundations, 4,182 cubic yards, at $6.50	27,183
Coursed rubble (quarry or rock-faced masonry) above foundations, 1,197 cubic yards, at $10	11,970
Cut-stone masonry, 1,900 cubic yards, at $13	24,700
Four gate-leaves	10,000
Wickets and maneuvering machinery	3,000
Crib-work above and below lock	2,000
Total for lock proper	102,545
Lock-keeper's house	2,000
Contingencies, 10 per cent	10,455
	115,000

My rough estimate last year for this lock was $110,000. By some mistake this estimate was forwarded as an estimate for the "dam," although the preceding discussion was entirely confined to the "lock." On this point, therefore, my report for 1873–'74 should be corrected.

DAM AT LAUREL RUN.

It is not necessary at present to have a larger appropriation than will suffice for building the lock, as it will take two seasons to finish it, although preparations for building the dam should be begun when the lock is half done, so as to have everything on hand for completing the entire work in the season following the completion of the lock.

The reasons previously urged in favor of a stone instead of a wooden dam at Hoard's Rocks have caused me to estimate only on a stone dam at Laurel Run. Owing to the depth to which we must go to reach rock, there will probably be no material difference in cost between the two constructions; and the stone dam would be very much tighter, a very important consideration in this case, as the Upper Monongahela is sometimes very low in the summer and fall.

Estimate on dam.

Earth-excavation, 1,945 cubic yards, at $1	$1,945
Rock-excavation, 1,945 cubic yards, at $2	3,890
Coffer-dam, 1,250 feet, at $4	5,000
Riprap filling between coffer-dam and dam, 5,000 cubic yards, at 50 cents	2,500
Dry stone masonry, 2,140 cubic yards, at $4	8,560
Uncoursed rubble masonry, 1,900 cubic yards, at $6.50	12,350
Coursed rubble, (quarry or rock faced masonry,) 2,383 cubic yards, at $10	23,830
Uncoursed rubble in abutments, 700 cubic yards, at $6.50	4,550
Cut-stone masonry, for coping, 347 cubic yards, at $13	4,511
	67,136
Contingencies, 10 per cent	6,864
	74,000

Summary.

Lock, with lock-keeper's house	115,000
Dam	74,000
Total for lock and dam	189,000

It will be observed that the estimate for the lock differs but slightly from the rough estimate made last season, and the difference is less than the allowance for contingencies.

The cost of the dam will considerably exceed the cost of the one at Hoard's Rocks, because it is considerably longer, and because the facilities for obtaining stone are apparently not so good at Laurel Run. The new dam will be 625 feet in length, while that at Hoard's Rocks is only 400 feet. After stone-quarries are opened, I propose revising the present estimate and adding an estimate for a wooden dam, as it may be thought best to build of wood for the sake of economy. No present action is needed on the estimate for the dam, and it is only made in order to give an idea of the total cost of the whole work.

I would urgently request that the whole sum needed be appropriated at one time for the lock at Laurel Run, in order to save the great loss that always ensues when contractors are changed on an unfinished work. If this cannot be done, I would suggest that I be allowed to make a conditional contract for the whole lock, dependent upon subsequent action of Congress, but not binding unless Congress makes an additional appropriation; or else that the appropriations be held back until their sum amounts to the sum required to let a contract for the entire lock. It would be best to build by day's labor were it not for the eight-hour law.

Financial statement.

Balance in Treasury of United States July 1, 1874	$103,000 00
Amount in hands of officer and subject to his check (including $403.84, percentage due on contracts not yet completed) July 1, 1874	5,470 73
Amount appropriated by act approved March 3, 1875	22,000 00
Amount expended during the fiscal year ending June 30, 1875	29,184 64
Amount available July 1, 1875, including $3,213.78 due on contracts	101,286 09
Amount required for the fiscal year ending June 30, 1877	115,000 00

P 3.

WABASH RIVER.

Mr. F. Stein has been throughout the year the assistant engineer in general charge of the work of improvement on this river.

At the beginning of the fiscal year, but one contract was outstanding, that with Messrs. Myers & De Ham, dated June 28, 1873, for the improvement of the channel at the Grand Chain. More than half the work was done in the year 1873, and it was completed on the 3d of December, 1874, the excavation during the fiscal year having amounted to 11,920 cubic yards, and the total excavation to 26,630 cubic yards.

The result of this work has been to make a great improvement in this difficult shoal, but experience has shown that when the dikes are submerged, there is a current across the excavated channel which has injured the east dike. The head of the west dike also needs a greater flare to the west. As the work was only completed last fall, there has been no opportunity since then to examine it thoroughly and to repair deficiencies. During the season of low water, I will make a personal examination, and endeavor to devise means to remedy these defects. In the main the work is a substantial success.

The appropriation act of June 23, 1874, contained a clause authorizing the purchase of all the property, rights, and franchises of the Wabash Navigation Company. This has been done, at a cost of $7,000.

No work was done last season except at the Grand Chain, as the act of June 23, 1874, forbade the expenditure of any portion of that appropriation until the rights and franchises of the navigation company were extinguished. This was not done until so late in the season that it was considered better to postpone making contracts until the spring of 1875. As a rule, river-work on the Wabash can only be done between June and December, and during this period it is often interrupted.

Under the appropriation act of March 3, 1875, $40,000 was appropriated for the Wabash River. With this sum, and about $10,000 left over from the preceding appropriation, the following contracts were let on the 17th of May, 1875:

No.	Work.	Contractors.
1	Dam across cut-off at New Harmony	J. M. & R. B. Kerr.
2	Rock-excavation at Warwick's Ripple	M. W. Nolan.
3	Clearing out cut-off at Little Chain	C. M. Cole.

During May and June no work could be done on the first two contracts on account of high water, but on the third work was begun on the 3d of June, and good progress toward clearing the cut-off of snags has thus far been made.

There is good reason to expect that before this report reaches Congress the first and third contracts will be completed, but the second will probably require two seasons.

SURVEYS.

During the year the following special surveys and drawings have been made:

Grand Chain, showing condition after improvement.
From Mink Island to Williams's Ferry, (including Warwick's Ripple.)
From Williams's to Marshall's Ferry.
Design for dam across New Harmony Cut-off.

ESTIMATE FOR 1876–'77.

There are many minor improvements yet to be made on the Lower Wabash, such as wing-dams, snagging, and dredging, on which Mr. Stein has reported to me in detail. But none of these obstructions are very great, and they are not worthy of mention so long as a very serious obstruction, affecting the commerce of the whole Wabash Valley, remains untouched. For this reason I have concluded to suppress this part of Mr. Stein's report, in order to concentrate everything on the great obstacle, the Grand Rapids dam.

In all of my annual reports I have strongly urged that everything should be put on the Grand Rapids lock and dam. The only reason why this has not been done hitherto is that the appropriations have been too meager to justify a contract, and the eight-hour law prevented me from doing satisfactory work by day's labor. I feel it my duty however, to reiterate the statement that one great barrier to the navigation of the Wabash River is the Grand Rapids, and that all others are insignificant, and should be laid aside until this one is overcome Mr. Stein writes as follows: "I respectfully report what I have stated in my former reports, that while the improvement of the river below Mount Carmel is a great benefit to the people living near it, this benefit will be increased tenfold by the action of the new lock and dam at Grand Rapids, by means of which only it is possible to navigate the river in its whole length from its mouth up to La Fayette, in Indiana."

I therefore submit the following

ESTIMATE.

For rebuilding Grand Rapids lock	$130,000
For engineering and contingencies	15,000
	145,000

Financial statement.

Balance in Treasury of United States July 1, 1874	$40,000 00
Amount in hands of officer and subject to his check (including $2,647.80, percentage due on contracts not yet completed) July 1, 1874	7,984 05
Amount appropriated by act approved March 3, 1875	40,000 00
Amount expended during the fiscal year ending June 30, 1875	38,067 02
Amount available July 1, 1875	49,917 03
Amount required for the fiscal year ending June 30, 1877	145,000 00

P 4.

EXAMINATION OF THE LITTLE KANAWHA RIVER, BELOW BULLTOWN, WEST VIRGINIA.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, January 9, 1875.

GENERAL: I have the honor herewith to forward the report of my assistant, Mr. E. J. Carpenter, on the examination of "the Little Kanawha River, below Bulltown," which was ordered in the appropriation bill for rivers and harbors, approved June 23, 1874.

The Little Kanawha River has already been improved from its mouth to Spring Creek, a distance of forty-three miles, by the construction of four locks and dams, having the lifts of 15 feet 9 inches, 10 feet 2 inches, 11 feet 10 inches, and 12 feet, respectively; making a total lift of 49¾ feet in this distance.

From the head of the present slack-water to Bulltown the distance is eighty-seven and three-quarters miles, and the rise is 151¼ feet; therefore, to continue the present system of improvement, giving 4 feet at Bulltown, would require twelve more locks and dams, with an average lift of 12 feet 7 inches.

Mr. Carpenter was informed that the cost of the upper lock and dam of the existing improvement was $40,000, and on this information he based his estimate of $480,000 for completing the improvement to Bulltown, which sum, however, he considers "very low for first-class work." Mr. Carpenter may have been misinformed as to the cost of lock and dam No. 4; at any rate, I am satisfied that the amount named is insufficient to secure first-class work, and none other is worth construction. Inferior work is not specially objectionable when used above water, where it is always fully under the eye of those responsible for its safety, but in subaqueous work it is folly to construct anything that is not strictly the best possible. The severest strains on submerged constructions come at a time when they are invisible, and when it is impossible to detect the weaknesses that might easily be strengthened if they were perceived, but which, by neglect, become entirely uncontrollable. So many cases of the destruction of river locks and dams, due entirely to mistaken economy in first cost, have come under my notice, that I feel bound to enter my protest against such work by making my own estimates fully up to what experience shows that they should be, if the works are expected to be permanent.

The existing locks on the Little Kanawha are 143 feet by 23, with an average lift of 12 feet 5 inches. As it would hardly be worth while to make the locks above Spring Creek larger than those already built below it, we are thus in a measure compelled to accept these dimensions for an upward extension of the slack-water system. As the examination of the Little Kanawha was greatly hurried by lack of funds, it was impossible to make definite locations of locks and dams, and, therefore, the character of foundation must be assumed in the estimate.

Mr. Carpenter reports that he believes the river-bed to be underlain by rock at but a slight depth, and, therefore, I will assume rock-foundations. Wherever rock cannot be found at reasonable depth, the work will be increased in cost.

ESTIMATE.

Lock 143 by 23 by 12½ feet lift.

Excavation for foundation	$6,000
781 cubic yards cut-stone masonry, at $12	9,372
526.26 cubic yards quarry-face masonry, at $8	4,210
1,892 cubic yards rubble masonry, at $6	11,352
Four gates with anchorages, at $1,000	4,000
Movable timber-dam at head of lock, (for use in case of accident to the gates)	100
Wickets and culvets in wall for filling and emptying	1,400
Crib-work above and below locks	1,000
Total	37,434
Contingencies, about 7 per cent	2,566
Total for lock	40,000

Wooden crib-dam, 300 feet long.

30,270 cubic feet timber, at 25 cents	$7,567
18,800 pounds spikes, at 6 cents	1,128
Rock-excavation for foundation	1,800
Masonry abutment	3,000
Coffer-dam	2,000
Riprap filling for cribs, 3,000 cubic yards, at $1	3,000
Total	20,495
Contingencies, about 7½ per cent	1,505
Total for one dam	22,000

SUMMARY.

One masonry lock	$40,000	
One wooden crib dam	22,000	
One lock and dam	62,000	
Twelve locks and dams will therefore cost		744,000
It will probably be necessary to build lock-keepers' houses at each dam. One of these will cost about $1,200. We must therefore add—		
Twelve lock-keepers' houses, at $1,200		14,400
Total		758,400

This is approximately the cost of this improvement on the supposition of rock-foundations for locks and dams. Gates that would last reasonably well could be built for less money than $1,000 apiece, including anchorage; but the saving in total cost would be slight, and I think that it would be judicious to incur a greater first cost, and thus secure more lasting and more satisfactory work.

The cost of wickets and culverts for filling and emptying the lock has been made a separate item, because it is contrary to the best practice to put wickets in the gates themselves, both on account of the weakening of the gates and on account of the dangerous jet which is caused by the flow from the wickets when the upper gates are placed on a lift-wall. This jet can be avoided by making the upper gates as deep as the lower ones, so that the flow into the chamber may take place under water. But this adds greatly to the weight of the gates and to the pressure supported by them, and makes it more difficult to prevent stones, gravel, and pieces of wood from getting into the head-bay and interfering with the necessary maneuvers. It is much better to fill large river-locks through culverts in the walls, and to empty them by direct discharge into the river through culverts in the river-walls. This method of emptying does away with the violent discharge into the tail-bay, which makes it difficult for boats to approach the foot of the locks, while, by retaining two valves in the lower gates, a sufficient flow is preserved to prevent the choking of the lower entrance to the locks by the formation of deposits.

The estimates given must be largely increased if rock foundations cannot be found at slight depth.

For a statement of the probable commerce on this impovement, I must refer to Mr. Carpenter's description of the country.

Should the cost of extending the existing slack-water system be considered too great, it might be considered proper to appropriate a small sum for the removal of the Beaver Rocks and the rock in Nailor Bend, and for clearing out the snags and fallen trees. For this work I would estimate as follows:

Removal of Beaver and Nailor Bend Rocks:	
Five hundred and fifty yards rock-excavation at $4	$2,200 00
Three months' snagging, at $1,700 per month	5,100 00
	7 300 00

This sum could be judiciously expended in any event.

One map and one profile accompany this report.

Respectfully submitted.

WM. E. MERRILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

REPORT OF MR. E. J. CARPENTER, ASSISTANT ENGINEER.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, December 31, 1874.

COLONEL: I have the honor to submit the following report of the survey of the Little Kanawha River, from Bulltown to Parkersburg, assigned to me by your orders August 21, 1874.

A survey of the river was made in 1838 by Mr. C. Crozet, then engineer of the Virginia board of public works. I have succeeded in getting a tracing of the map made from this survey, and a copy of it accompanies this report. As the Little Kanawha Navigation Company had run a line of levels from Parkersburg to Nettle Run, I proceeded to the latter point and continued it to Bulltown.

The annexed table of shoals, elevations, &c., and the accompanying profile of the river, are from these notes. The distances are in part from Mr. Crozet's map.

The Little Kanawha River is formed by the confluence of what are called the Right and Left Forks of the Little Kanawha, in the eastern part of Braxton County, West

Virginia. Its headwaters are very near those of Buckhannon River and of West Fork, both of which are tributaries of the Monongahela, and also near those of Elk River, an important branch of the Great Kanawha.

Its general course is northwest, through Braxton, Gilmer, Calhoun, Wirt, and Wood Counties, to the Ohio River at Parkersburg. In the western part of Gilmer County it runs south of west for about twelve miles. The river is very crooked and full of sharp turns, especially in Calhoun and Wirt Counties, where, in a direct distance of twenty-four miles, the river makes fifty-three.

With its tributaries, the Little Kanawha drains Wood, Wirt, Ritchie, and Gilmer Counties, the greater part of Calhoun, Roane, and Braxton, and portions of Lewis, Upshur, and Doddridge, an area of about three thousand two hundred square miles.

The country through which the river runs is extremely rough, with hills the entire length of it.

Above Burning Springs the river-bottoms are seldom more than a few hundred feet in width, and the country is very thinly settled. Below this point, in Wood County, the bottom-lands are somewhat wider, and the country is as thickly settled as any other part of the State, Parkersburgh, with a population of 5,546 in 1870, being in size the second city in the State.

Elizabeth and Burning Springs, in Wirt County, Grantsville, in Calhoun, Glenville, in Gilmer, and Lumberport, in Braxton, are the only towns on the river. They have from one to two hundred inhabitants each, and serve as distributing-points for supplies to the surrounding country, most of them having several stores. Elizabeth, Grantsville, and Glenville are county-seats.

This part of West Virginia is covered with a fine growth of poplar, oak, ash, walnut, and chestnut timber, except along the river and its large tributaries, where it has been cut away as far up as Lumberport. At present there is a very extensive trade in barrel-staves from Elizabeth to Glenville. In the vicinity of Burning Springs alone there were about five millions of staves collected awaiting the completion of the locks below for shipment to Parkersburgh, and thence to Aurora, Ind.

It is said, however, that the trade in staves is rapidly diminishing, as the kind of timber required (perfectly clear, straight-grained oak) is becoming scarce on the river and on the large creeks.

Very little lumber is manufactured for exportation, except at Elizabeth, twenty-six miles from Parkersburg, and at Lumberport, one hundred and twenty-two miles. At the latter place Messrs. Byrnes Brothers & Hoffman have very large saw-mills, and cut annually about two million feet of lumber of various kinds. This lumber is shipped to Parkersburgh, being floated down in flat-boats. Besides lumber and staves, the exports of this part of the State amount to very little. Grain is raised, but only in quantities sufficient for home consumption, and as the country is so rough, it will probably never produce more than can be disposed of by the people themselves.

At some points there is good grazing-land, and the production of wool and cattle is generally about equal to the demand for them.

At Bulltown there were quite extensive salt works, but no salt has been produced for four or five years. Coal is found in the hills all along the river from Burning Springs up, but, except between Glenville and Lumberport, the seams are only from 12 to 20 inches in thickness, and do not furnish a very good quality of coal.

At Burning Springs several banks in the 20-inch seam are worked, but only the high price received for the coal, eighteen cents per bushel at the bank, justifies working a seam of this thickness.

At Lynch's saw-mill, three miles above Glenville, a seam of coal from 5 to 7 feet in thickness appears at an elevation of about 80 feet above the river-bed. It dips to the southeast, disappearing below the river-bed and re-appearing at about three miles below Lumberport, where it is worked, the openings being about 30 feet above the river. It runs out of the hills again a few miles farther on.

At Stout's mill it is said that several years ago, when the mill-dam broke during a rise, the water cut through the stone river-bottom and washed out a quantity of coal. The mine at Lynch's saw-mill has been worked for more than twenty years, though not systematically. It has a smooth, hard roof, and floor of slate, and the coal is removed by blasting. One man in this mine takes out from three to four hundred bushels per day. He intends shipping the coal as far down the river as Elizabeth. At this bank coal loaded into boats is sold for 6 cents per bushel. At the bank above Stout's mills the price is 3¼ cents per bushel at the mouth of the mine. Most of the coal from this place is hauled to Lumberport.

The river is so narrow and during high water, the only time when coal could be shipped, has so swift a current that it is almost impossible for large boats loaded with coal to get around the frequent sharp bends without going ashore, or becoming entangled among the trees and bushes that cover the banks to the low-water line.

For this reason I do not think that this coal can ever be taken to market at rates that will permit it to compete with that on the Big Sandy and Great Kanawha Rivers, although it is of excellent quality, and very easily mined.

Some years ago a company attempted to mine this coal, but the losses in transportation by the river were so great that they were obliged to stop.

The Little Kanawha Navigation Company have built four locks and dams, making slack water not less than four feet at low water, from Parkersburgh to Spring Creek, a distance of forty-three miles. The work was commenced about 1867, and completed early in the present month. The object of the improvement originally was to furnish transportation to Parkersburg for the coal-oil that was then produced in great quantities at Burning Springs. The work was delayed for various reasons, and now the wells have stopped flowing. The price of oil has declined so much that it does not pay to pump the wells, and very little oil is now produced. The company expect, however, that the tolls on rafts and manufactured lumber will pay a fair interest on their investment.

All of the locks and dams seem to be very substantially built. The lock-chambers are 143 feet long and 23 feet wide. The dams consist of cribs 10 feet long, built of sawed oak timbers 12 inches square, and well bolted together. They are filled with broken stone, and protected on the upper side by a double row of sheet-piling.

Three of the dams are built with four steps on the lower side, so arranged as to break the fall of the water and prevent undermining.

The dams are 42 feet wide on the base, and are well anchored to the river-bottom, which in almost every case is of solid rock for nearly the full width of the river. All the stone for the work was taken from the river-banks, and in only one case had to be transported more than a few hundred yards.

The fall of the river from Bulltown to Leading Creek, a distance of about thirty miles, is 2.49 feet per mile. From Leading Creek to Spring Creek, fifty-eight miles, it is 1.35 feet per mile, and from Spring Creek to Parkersburg, forty-three miles, it is 1.16 feet per mile. From Bulltown to Spring Creek, the head of the present slack-water navigation, the fall is 147.64 feet, or 1.69 feet per mile.

I do not think that it would be advisable to build dams on this part of the river higher than they are below, for, although the river has less oscillation, the banks are not so high, and the bottom-lands might be in greater danger of overflow.

Twelve locks and dams, with an average lift of 12.6 feet, would therefore be required to give a minimum depth of 4 feet of water for this distance.

The cost of the four locks and dams built by the Little Kanawha Navigation Company is said to be about $240,000. The cost of the locks above would probably average about the same as lock No. 4 of the present system. As the dams would have less length, their cost would probably be somewhat less. Taking the cost of lock and dam No. 4 as a basis, I estimate the total cost of the improvement at $480,000, or an average of $40,000 for each of the twelve.

I consider this estimate very low for first-class work.

The bottom of the river is usually of sand or gravel, with large bowlders. The navigation company found rock bottom for all of their dams except one; and, although the rock does not ordinarily appear on the upper river, I am of opinion that the sand or gravel covering is usually of slight depth.

Below Yellow Creek the bottom-lands are seldom less than 35 feet above the river-bed. Above this place they are from 6 to 10 feet lower.

Back-water from the Ohio River has been known to extend as far up as Burning Springs. At this place the Little Kanawha has a range of 37 feet between high and low water.

At Rice's Ripple I found the high-water mark of 1852 to be 38 feet above low water, and that of several rises in the spring of the present year was 23½ feet. At De Kalb the mark of the flood of 1852 was 36 feet above low water, and ordinary rises reach 24 feet.

At Lumberport the marks of several rises last spring showed a height of 13 feet; and the highest mark that I was able to find showed a rise of 24 feet.

From the profile it will be seen that any radical improvement of the river other than by locks and dams is impossible. Rock bottom at various places prevents dredging; and, in any event, the great fall of the river above Spring Creek, and the very limited supply of water during four or five months of the year, make it impossible to accomplish any good by this method, or to obtain more water than there is at present on the ripples. Rafts and heavy flat-boats seldom run on less than 8 feet of water, from 4 to 6 feet more than their draught; for the swift current renders it impossible to keep the channel closely going round the numerous bends. At this stage there is no danger from snags, nor from the rocks that ordinarily cover the ripples. At Nailor's Bend, however, there is a very dangerous rock standing 6 feet above low water, and so situated that it seems almost impossible for a raft to pass without going over it, as in fact they usually do. This rock was formerly several feet higher, but was cut down by blasting. Its base is about 12 by 15 feet.

Beaver Rocks, a short distance below, extend 9 feet above low water, and 50 feet from the bank of the river. They cover an area of 35 by 40 feet.

The pools between the ripples are of various depths, and below Grantsville they range from 6 to 20 feet in depth at low water. From Grantsville to Lumberport the depth on the pools is seldom more than 4 feet greater than on the ripples.

From Lumberport to Bulltown the river is little more than a succession of small ripples.

Mr. James McArthur, engineer of the navigation company, found the supply of water at Burning Springs to be sufficient for thirty lockages per day during extreme low water.

I made a few rough gaugings with the following results: At Bull River Shoals the flow was 12.58 cubic feet per second, or water sufficient for about twenty-one lockages, allowing for leakage about 25 per cent. of the whole amount. At Hays's Bar the flow was 6.72 cubic feet per second, enough for nineteen lockages.

Very respectfully, your obedient servant,

E. J. CARPENTER.

Col. W. E. MERRILL,
United States Engineers.

Little Kanawha River, West Virginia.

[The elevations and distances are those of the foot of the shoal, as the survey was made while ascending the river.]

Miles from Parkersburg.	Name.	Elevation above low water, Ohio River, at Parkersburgh.	Elevation above low-tide of ocean.	Fall, in feet.	Length, in feet.	Remarks.
0	Parkersburg	0.00	563.612			
3½	Shacktown	0.00	563.612			
3½	Lock No. 1			15.7		
	Pool No. 1	15.731	579.343			
14	Leachtown	15.731	579.343			
	Lock No. 2			10.1		
	Pool No. 2	25.907	589.519			
17	Hughes River	25.907	589.519			
22	Wells's Ripple	25.907	589.519			
	Lock No. 3			11.8		
	Pool No. 3	37.730				
26½	Elizabeth	37.730	601.342			
32	Palestine	37.730	601.342			
	Lock No. 4			12.0		
	Pool No. 4	49.725	613.337			
38½	Burning Springs	49.725	613.337			Head of slack-water navigation.
44	Buffington Shoals	49.907	613.517	3.9	2 690	This fall includes Cow Ripple and Island Run Shoals.
45	Cow Ripple					A large rock bar on north side of river.
47½	West Fork Ripple	53.853	617.465	4.1		Ripple just below the mouth of West Fork. It is the worst place below Muscle Shoals; very shoal and swift at the site of the old Depew dam, where there is solid rock bottom.
50½	Flat or Two-Run Ripple.	57.978	621.590	5.7	10 560	Very shallow; river wide and bottom flat; gravel and bowlders.
52¾	Beaver Rocks					Extend with the river about 60 feet, and rise 9 feet above low water; they cover an area of 35 by 40 feet, and are very dangerous to the rafts and flat-boats.
53½	Nailor Bend	64.708	628.320	1.4	900	Swift current and shoal water; in the bend is Nailor Rock, 50 feet from the right bank and 6 feet above low water.
56	Mouth of Lower Leading Creek.	68.901	632.513	3.3	900	Remains of an island in the river; gravel and sand bar on the right bank grown over with brush.
61	Deveise Ripple	72.428	646.040	2.5	2,400	River wide and shallow; sand and gravel bottom; large sand-bar on left at head.
62½	Downs's Ripple	74.980	638.592	1.0	600	Gravel and sand bottom, with large flat rocks.
63½	Mouth of Anna Maria Creek.	75.968	639.580	2.5	750	Remains of an old dam near the right bank; coarse gravel bottom.
66½	Stocking Run	79.043	642.655	1.8	450	A large gravel-bar on the left, making a narrow channel and swift current.

Little Kanawha River, West Virginia—Continued.

Miles from Parkersburg.	Name.	Elevation above low water, Ohio River, at Parkersburg.	Elevation above low-tide of ocean.	Fall, in feet.	Length, in feet.	Remarks.
68½	Big Root Shoals	81.210	644.822	3.1	1,350	River 200 feet wide; bottom flat; rock bottom on right at foot; large rocks on bank at foot.
73½	Beall's Ripple	84.337	647.949	6.7	1,500	This fall includes Heardman's Ripple.
75	Heardman's Ripple	....	....	.....	.....	
76	Mouth of Pine Creek	91.023	654.635	1.0	22.5	Channel very crooked; large gravel-bar on left at foot.
77½	Mouth of Leaf-Bank Run.	91.969	655.581	1.0	300	A large gravel-bar on the right at foot; channel very crooked.
				5.00	4,300	Half a dozen small ripples from Leaf Bank to Grantsville; shoal all along.
78	Grantsville	97.101	660.713	1.8	250	
79	Bull River Shoals	98.965	662.307	1.0	210	River 240 feet wide; gravel-bar on right.
80	Hoffman's Ripple	99.538	663.150	2.1	2,175	Gravel-bar 6 feet high on the right, covered with trees and brush; rocks on the left near foot 9 feet high; channel 70 feet wide; stumps and snags at foot.
83	Steer-Creek Ripple	103.196	666.808	2.4	600	Channel full of large bowlders; wide and shallow.
85	Rice's Ripple	107.469	671.081	0.9	600	
86	Acre Island	108.271	671.883	1.4	1,020	Island covered with trees and brush; gravel-bar 4 feet high at head; two large rocks on left bank of river, one 5 feet and the other 12 feet high; high-water channel 75 feet wide.
87	Laurel Shoals, mouth of Laurel Creek.	109.637	673.249	3.2	1,350	River divided into two channels by an island, covered with trees and bushes; channel on left; gravel-bar 4 feet high at head.
89	Muscle Shoals	114.061	677.675	4.5	2,280	A small island at foot of the shoals and one at the head; low gravel-bar on left, at head of ripple; the channel is narrow and very crooked; current swift. This is considered the worst place on the river.
90	Buck Shoals	118.549	682.161	0.8	150	Very narrow channel; gravel-bar at head 3 feet high.
92	Tanner's Fork	119.780	683.392	0.3	150	Sand-bar above ripple; pile of snags on right.
	Shanty Run	120.057	683.649	1.4	210	Narrow, crooked channel.
	Fishpot Shoals	121.395	685.007	1.3	200	Small island, 6 feet high, at head of shoals on left.
93	Mill-Seat Ripple	122.706	686.318	0.2	510	River wide and very shallow; pile of snags extending two-thirds across the river.
96	Cedar Creek	123.903	687.515	0.4	240	River 216 feet wide from bank to bank; sand and gravel bottom.
98½	Third Run Shoals	125.176	688.788	1.4	725	Channel 80 feet wide at foot of shoals, and very crooked, making a sharp turn to the left; gravel-bar, 5 feet high, at head.
99½	Stinking Creek	....	....	.....	.....	
101	Leading Creek	129.257	691.527	2.0	2,280	Channel very crooked; trees touch across river; sand and light gravel bottom; quicksand at mouth of creek.
101½	Red Oar Bar	129.257	692.869	2.0	....	Steep rock bank and rock bar on right; bar 4 feet high.
103	Glenville	132.162	695.774	7.3	....	Hardman's mill-dam has a lift of 5.7 feet when full; at time of survey, 4.2 feet.
105½	Stewart's Creek	139.439	703.051	0.4	135	
106	Hays's Bar	141.004	704.616	0.8	450	
107	Mud-Lick Run	144.427	708.039	2.8	750	
110½	Sand Fork Ripple	148.756	712.368	1.4	1,050	
	Second ripple above Sand Fork.	150.494	714.106	1.5	1,050	Solid rock bottom full width of the river; two rock bars.
	Stout's Ripple	151.983	715,595	1.8	120	
112½	Dusk Camp Run	154.077	717.689	5.6	2,100	Large gravel-bar on left, at foot, covered with brush; gravel-bar on left, at head; river makes a sharp turn to the right; bottom, coarse gravel.

Little Kanawha River, West Virginia—Continued.

Miles from Parkersburg.	Name.	Elevation above low water, Ohio River, at Parkersburg.	Elevation above low-tide of ocean.	Fall, in feet.	Length, in feet.	Remarks.
113½	Stout's Mill	160.081	723.693	0.1	....	
	Holt's Ripple	160.439	724.051	2.8	900	
	First ripple above Copen Run.	163.955	727.567	2.0	900	
	Second ripple above Copen Run.	165.921	729.533	2.2	1,350	
118½	Hyer's Run	168.619	732.231	3.5	450	River, at low water, 20 feet wide.
119½	Buffalo Shoals	172.144	735.756	5.9	2,220	River 225 feet wide; long island, 4 feet high, covered with brush; gravel-bar, 3 feet high, on right, at foot.
121¼	Oil Creek	178.007	741.619	0.0	....	
122	Lumberport	178.007	741.619	1.3	....	Between Lumberport and Cutlip's mill are six ripples, with an aggregate fall of 4.1 feet.
124	Cutlip's Mill	183.336	746.948	4.7	600	
127	Bennet's Run	188.001	751.612	1.1	300	From Bennet's Run to Bulltown are thirteen ripples, with an aggregate fall of 7.6 feet.
130½	Bulltown	197.364	760.976	......	....	

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EXAMINATION OF GUYANDOTTE RIVER, BELOW LOGAN COURT-HOUSE AND TWELVE-POLE RIVER, BELOW WAYNE COURT-HOUSE, WEST VIRGINIA.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, January 12, 1875.

GENERAL: I have the honor herewith to forward the reports of the examination of the Guyandotte and Twelve-Pole Rivers, ordered in the last appropriation act for rivers and harbors, approved June 23, 1874.

As the sums allotted for these surveys were very small, I endeavored to put them in charge of some one who was already familiar with the country. I fortunately found at Cabell Court-House, (Barboursville,) on the Guyandotte, Mr. Arthur L. Cox, who had already partially surveyed the valley of the Guyandotte River in the interests of a railroad. He undertook both examinations, and his reports are hereto annexed.

GUYANDOTTE RIVER.

The distance over which the survey extended, from its mouth to Logan Court-House, is eighty-one and a half miles. In this distance the fall is 147¾ feet, or at the average rate of about 22 inches per mile. Mr. Cox considers the minimum discharge as 20 cubic feet per second. The extreme oscillation of the stream is 30 feet.

This river was once improved at the expense of the State of Virginia, by the construction of six locks and dams. Five of them have been washed away, (four wholly and one partly,) and the sixth is the greatest obstruction now to be found on the river. This is one of the many illustrations to be found in the United States of the total destruction of useful hydraulic works, either by the decay of the perishable materials used in construction or by radical defects in the plans of the engineers, who were employed because their services could be obtained at low rates. I have personally examined the relics of the lock and dam yet remaining, near the mouth of Mud River, and conclude that in this case the first-mentioned cause undoubtedly operated, and probably the second also.

Should an improved navigation be made on the Guyandotte, it will be chiefly useful in transporting to the Ohio River the mineral wealth, which is abundant in that portion of West Virginia, as the country is too broken to support a large farming or stock-raising population. For many years the timber-product will also be large.

Mr. Cox concludes his report by recommending that the draught on the miter-sills of the locks should be increased to 7¾ feet, in order to give an outlet for coal-boats, which draw, when loaded, about 7½ feet. I do not think that this extra expenditure would be judicious, as the greater proportion of the coal now transported on the Ohio is carried in barges which only draw 6 feet. A coal-boat is about 160 feet long and 26 feet wide, while a barge is 130 feet by 24 or 25. The latter is about as large a craft as could be conveniently managed on so narrow and crooked a river as the Guyandotte, even if it were slackwatered.

On the Monongahela it is considered sufficient to have 4 feet on the miter-sills at dead low water, because coal barges only run when there is a good boating-stage in the Ohio, and at such a time the Monongahela also is almost invariably at a good stage, and gives at least 2 feet more over the miter-sills.

For these reasons I would not, in this preliminary and necessarily approximate estimate, calculate on more than 4 feet on the miter-sills.

The question of the allowance to be made for foundations cannot be satisfactorily answered with the information at present available, but, by making as accurate an approximate estimate as our present knowledge will permit, Congress can form a general idea of the cost of the work, and will therefore be able to decide whether it is worth while to make a detailed survey, with exact locations for locks and dams, and exact estimates.

Mr. Cox recommends locks 160 feet in length and 60 feet in breadth. He says that lock No. 1 must rest on a pile-foundation, and that at the other locations "an excavation of from 10 to 15 feet will doubtless reach a solid stratum of sandstone." If stone cannot be found at a less depth than 15 feet, it will be more economical to build on piles. I will, therefore, assume a pile-foundation for all of the locks. Should bed-rock be subsequently found at any selected site within economical reach of masonry, the estimates that follow will necessarily be reduced. The number of locks required to reach Logan Court-House, with an average lift of 10 feet to a lock, will be 15. On the profile sites have been chosen for 17 locks with varying lifts; but, as the sites are only approximate, and may be changed on a more careful examination, I have thought it better for the purposes of the present report to estimate on a uniform lift of about 10 feet.

ESTIMATE.

Masonry-lock 160 *by* 60 *by* 10 *feet lift.*

Earth-excavation of banks and bottom	$8,000
Masonry-foundations and lock-floor, 1,284 cubic yards, at $6	7,704
2,800 cubic yards of rubble-masonry, at $6	16,800
860 cubic yards quarry-face masonry, at $8	6,880
900 cubic yards cut-stone masonry, at $12	10,800
Four gates, at $3,000	12,000
Wickets and culverts for filling and emptying	900
Temporary dam for head of lock	300
Crib-work at upper and lower ends of lock	1,000
	64,384
Contingencies and engineering, about 10 per cent	6,616
Total for one lock	71,000

Wooden crib-dam 300 feet long, 10 feet lift.

Coffer-dam	$2,000
Excavation—1,000 cubic yards, at 70 cents	700
32,000 cubic feet of timber, at 25 cents	8,300
15.200 pounds spikes, at 6 cents	912
2,363 cubic yards riprap for filling, at $1	2,363
Abutment	3,000
100 piles, at $15	1,500
600 sheet piles, at $3	1,800
Stringers, 300 cubic feet, at 30 cents	90
	20,665
Contingencies and engineering, 9 per cent	1,835
Total for one dam	22,500

Summary.

One masonry-lock	$71,000
One crib-work dam	22,500
Lock-keeper's house	1,200
	94,700

Fifteen locks and dams will, therefore, cost about $1,420,500.

If this sum should appear too great for the benefits to be derived, I think it might be judicious to spend some small sum in removing obstructions of various kinds, particularly the relics of the destroyed slack-water system. I have no information at hand to enable me to make an exact estimate of the sum needed, but I should think that $10,000 might be expended to advantage.

TWELVE-POLE RIVER.

This stream is more generally known as Twelve-Pole Creek, and is of inconsiderable magnitude. The distance from its mouth to Wayne Court-House is thirty-one and a half miles by river, and fourteen in an air-line. The fall in this distance is 79 feet, or at an average rate of 25 inches per mile.

The minimum discharge of Twelve-Pole is 2.1 cubic feet per second, a quantity altogether insufficient for maintaining a continuous navigation. If such a navigation were desired, it would evidently be necessary to construct reservoirs at suitable points in the hills.

The country along this stream is poorly adapted to agriculture, and will probably furnish no farm-products for exportation except fruit. There are iron deposits below Wayne Court House, but, as far as now known, they are inconsiderable in amount. Coal is abundant above Wayne Court-House, but to reach it at all would require an extension of any improvement to a point four miles above the limits of the present survey. One or two additional dams would be required to make the river available for coal-transport.

ESTIMATE.

To reach Wayne Court-House with locks of 10 feet lift will require eight locks and dams. The foundations are so nearly like those on the Guyandotte that the same estimates, with a slight reduction for the diminution in length of the dam, will answer for both.

One masonry lock, 160 by 60 by 10 feet lift	$71,000
One crib-work dam, 100 feet long	9,000
One keeper's house	1,000
One lock and dam	81,000
8 locks and dams	648,000

To reach the coal-fields probably two more dams will be required, making a total cost of $810,000.

The cost of the reservoir that would be required to keep up navigation during the low-water months cannot now be determined for lack of data.

Mr. Cox concludes his report as follows:

> In conclusion, I can see no present or prospective necessity for the execution of this work, nor do I think it practicable.

I agree with him that there seems to be no present necessity for attempting to establish slack-water on Twelve-Pole.

It might be advisable to appropriate some small sum, say $5,000, for removing the obstructions in this stream. The worst obstructions, however, seem to be mill-dams, which probably have obtained such legal rights that they could not be disturbed without preliminary process of law. Whether the Government could get them away without payment of damages I am unable to state.

A map and a profile of each river accompany this report.

Respectfully submitted.

WM. E. MERRILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

REPORTS OF MR. A. L. COX, ASSISTANT ENGINEER.

1.—*Guyandotte River, West Virginia.*

This river rises in the Cumberland range of mountains, and flowing in a northwesterly direction, through the counties of Wyoming, Logan, Lincoln, and Cabell, empties into the Ohio River at the town of Guyandotte, Cabell County, one hundred and sixty-four miles above Cincinnati, Ohio. This survey extended from the mouth of the river to Logan Court-House.

The valley of the Guyandotte River is caused by the erosion of the rocky strata peculiar to the true bituminous coal-measures. It gradually becomes narrower, and the hills increase in height as we ascend the stream, the vertical height of the hills at Logan Court-House being 1,250 feet above low-water mark of the river. There are no table-lands in all the Guyandotte Valley, the various tributaries and branches of tributaries to the river having each to itself a similar valley of erosion. Thus, all the region of country drained by this river is cut into valleys divided by sharp ridges, and probably one-fourth of the surface of the valley above the level of the water-courses has been worn away.

From the mouth of Mud River to a point, say, forty miles above Logan Court-House the Guyandotte River receives no tributary which contributes anything to the volume of the river except in a rainy season. This is a marked peculiarity of the physical features of the stream; and it thus results that in the dry season the volume of water at Logan Court-House fully equals, if not exceeds, that within a few miles of the mouth.

The scenery is, indeed, noble, and in full autumnal tints the long sweep of forest-clad mountain presents to the traveler's eye an ever-varying picture of surpassing beauty.

From the mouth of the river to the falls the river-bed is a continuous declivity with a sandy bottom. Above the falls we have alternate pools and shoals, the latter of small irregularly-shaped sandstone. The river-bed varies in width from 250 to 350 feet, with alluvial banks from 40 to 60 feet in height, to the level of the bottom-lands. The banks are of sand and clayey earth, and where stripped of forest-trees and shrubs are easily destroyed—worn away by the action of the river-floods. They may safely be declared exceedingly unstable. In many places the bottom-lands are filled with craw-fish that have "honey-combed" the territory from the river-side to the base of the mountains.

The distance from Logan Court-House to the mouth of the Guyandotte River is 81½ miles. The total fall of the river in this distance is 147.76 feet. I have taken great pains to ascertain the minimum volume of water discharged by this river. From September 20 to November 12 of this year there was but a slight rain-fall in this portion of the State. A cross-section of the river on the 16th of October gave a flow of 110.8 cubic feet per second. Another computation, based upon observations of the river November 12, 1874, gave a flow of 30 cubic feet per second.

I think we may safely conclude that the discharge of this river will never fall below 20 cubic feet per second, while for the most part of the three dry months the river will yield a volume of 40 feet per second, and probably for nine months of the year the supply will reach from 120 to 170 feet per second.

The vertical rise of the river is very great. The best measurement obtained was at Rogers's Mill. The weir is 300 feet in length, with 6 feet vertical height, and a shoal with several feet fall below; and the vertical rise—the depth of the flood of water—between 25 and 30 feet. This is the extreme flood of the river; but when the lands of the valley shall be measurably cleared of forest-trees we may reasonably predict that the changed condition of the water-shed will raise the high-water mark of the floods from 15 to 20 feet beyond the point which they at present reach. Nearly all the river-banks are lined with forest-trees, great numbers of which lean out over the river, and should be carefully cut away, so that in removing the obstructions no great damage would result to the banks, to which they are a great protection.

The principal obstructions to the present navigation of the river are the remains, six in number, of an old system of locks and dams, which were constructed some eighteen years ago. But one of these, Rogers's Mill, yet stands, and it is a very serious obstruction. At this place all boats are unloaded, and a portage is made; it ought to be removed. The other locks and dams have been torn away by the action of the floods, until, with one exception, they are out of the way. Dam No. 2 of the old system, near the mouth of Mud River, yet remains in part. It should be removed. The little mill-dams along the river are generally built at the top of the steeper shoals, and are from one to three feet in height. They are provided with a navigable pass. A portion of the dam is movable, and this taken out, floods all the shoal, and really improves the navigation as at present used.

The present navigation of the river serves to float out into the Ohio River small rafts of timber on the floods, and also to carry up stream all the merchandise and manufactured articles used in the country bordering upon the river. A slow and somewhat tedious method of transportation is carried on by means of "push-boats"—a kind of flat-boat, of from 50 to 80 feet in length and 7 feet in width. That portion of the river from the mouth to the falls, thirty miles, contains the chief obstacles to be overcome by these boats. At all times of low water, the volume of water is spread over the river-bed into numerous channels, that do not afford a sufficient depth for even this class of boats, unless they are very lighly laden. Above the falls the pools of water are from 3 to 20 feet deep, and present no difficult navigation to these boats. The shoals are improved by chutes constructed by the boatmen. They have removed the stones and dug passages a little exceeding the width of their boats, thus contracting the water-flow over the shoals. The removal of old lock and dam No. 2, and also of Rogers's mill-dam, would materially improve the present navigation of the river, as also would the straightening of the chutes over some of the shoals. The shallow water in the first thirty miles of the river, and also over all the shoals, materially restricts its use, and effectually bars a more extensive system of transportation. The only practicable method of improving the navigation would seem to be by a thoroughly-constructed system of locks and dams.

I have indicated upon the map and profile those points which seem, from superficial observation, to be best adapted to withstand the shocks of the enormous floods to which they will be subjected. More thorough and careful observations are necessary before determining their locations definitely. The irregularity of the list is to be regretted. The dam at Salt Rock could be reduced to 10 feet in height by excavations at the next dam, the falls; so also might some other irregularities be measurably corrected, but I have thought those points which promised the greatest degree of stability should be chosen; that the irregularity of the lift would prove a lighter evil than badly-taken situations for dam and lock sites.

It is recommended that the locks be built 160 feet in length and 60 feet in breadth. This will accommodate two barges, or a tow-boat and barge.

I also recommend that there be, as indicated on the profile, four feet of water on the miter-sill. This depth may be increased as the water falls in the early summer-season by a judicious use of boards, loosely fastened upon the tops of the dams, thus increasing both depth and supply of water, say 18 or 20 inches, above the natural levels of the dams.

The first dam and lock will, as seen upon map and profile, stand upon the bank of the Ohio River. This will require pile-foundations, which should be extended along the axis of the river several hundred feet. The lower side should be thoroughly protected from the "back-lash" of the floods, and what the northwestern lumbermen call "fingers" might here be used to a good purpose. I would suggest at this point a superstructure of cut free-stone. All the remaining locks and dams may, and should, be built of sandstone, of which there is an ample supply all along the river-valley. An excavation of from 10 to 15 feet will doubtless reach a solid stratum of sandstone at the other points designated for their location. This opinion is based upon the results of the examinations made in the Great Kanawha Valley during the present (1874) season. The similitude of the two valleys, their close proximity, and the identity of their stratification, point to the above conclusion. It would also be well that the river-banks be largely widened at lock and dam No. 1. The space between the foot-hills of the Ohio River Valley and the mouth of the Guyandotte, 3,500 feet, would thus be protected from any overflow from the erection of this dam. The stability of the structure would also be increased by this lengthening of the weir. At all other points where locks and dams are built, the river should also be widened, so that it shall clearly fall within the rule that "the rectangle of the weir shall exceed that of the river-banks above." This widening, too, throws the lock-wall, the lock, and both abutments out of the action of the current, and its accompanying accumulation of drift-wood incident to the floods of the river.

The Guyandotte River Valley is but ill-adapted to farming purposes, and, except fruits, I think will never furnish agricultural products which would, to any great extent, seek a market over the proposed slack-water navigation. There is something done at present in the way of raising stock, and this industry would probably increase. Timber and logs are the only product of the valley exported to any very great extent, and this is, as yet, in its infancy. James Neighbest, esq., of Logan Court-House, estimates the annual product at $300,000. Prof. James Bachman, of England, says of this valley, "As a botanist, I was astonished at the magnificence of the forest. There are valuable timber-trees, not scattered singly but covering all the country-side."

Prof. John Locke says: "Although the formation is, in general, sandstone, yet from the abundance of the decomposing shale the soil is rather clayey than sandy. The forests, although they contain a preponderance of oak, have a good share of trees such as sugar-maple, hickory, black-walnut, linden-tree, magnolia, and tulip-poplar."

The valuable woods are oaks, *Quercus alba*, *Q. rubra*, *Q. pinctoria*, *Q. castanea*, poplar or tulip tree; the hickories, *Carya sulcata*, *C. alba*, *C. tomentosa*, chestnut, beech, elm, and maple. Of these, but the white-oak, poplar, and black-walnut are sent away to market, but all varieties are being destroyed by clearing for farms.

The manufacture of wooden wares of all kinds would spring up all along an improved navigation, and thus turn to use much valuable timber now being yearly destroyed.

Thomas Thornburg, esq., of Cabell Court-House, for many years a merchant upon this river, estimates the yearly exports of all kinds from the valley at $400,000.

I have collected the number of tons which yearly go up the river from wharf-boat and river-men, and upon their estimates I place the figures at 300.

From Upper Two Mile to Logan Court-House there are continuous veins of bituminous coal of good workable depth above water. The notable veins opened are a vein of from 4 to 5 feet in thickness, in which there is some shale; a vein of 6 feet in thickness, which is very free from dirt; and a third vein, from 9 to 10 feet thick, with a vein of shale in the center of a thickness varying from 1 to 2 feet. Above Nine-mile Creek are veins of cannel-coal from 2 to 5 feet thick. I doubt if the cannel-coal strata can be relied upon as continuous; they may interchange with the other varieties, or they may "pocket." Their extent, however, is considerable, one vein showing along the hill-side in Big Ugly Creek for eighteen miles so often as to lead to the conviction that it is continuous for that distance.

Probably one-fourth of the coal-veins are worn away by erosion of the valleys, as heretofore stated, and from the frontage along the river-valley, for a distance of say seventy miles, much of the coal can be run down inclined planes, and dumped directly into coal-barges.

There exists fairly credible testimony that veins of coal exist below the water-level. In 1866 an effort was made at Mill Creek, half a mile above the falls, to obtain oil by means of boring; this disclosed the fact that coal existed in various strata of different-sized veins to a depth exceeding 600 feet.

It is suggested, with the greatest diffidence, that there exists near or not far below the mouth of Four-mile Creek a monoclinal axis, where the northwestern dip is largely increased; also, that at or near the mouth of Big Ugly Creek there exists an anticlinal axis, which makes the strata horizontal, or gives a southeast dip as far as Logan Court-House. This hypothesis will account for the appearance and disappearance of the large and upper vein of coal.

A second well was bored for oil at Brown's Trace Creek, twenty-three and a half miles from the mouth of the river. Its depth is nearly 1,300 feet, but no record of the successive stratification passed through can be found. At the above depth a vein of salt water was struck, which discharged the full size of the tube with violence. It has been partly plugged, but still flows a large quantity of salt water. It is stated that this well flows a saturated solution of chloride of sodium; a statement the accuracy of which I have no means of testing.

Nodular or "kidney" iron-ore is found scattered over all the valley, and occasionally in place, much of which would probably be mined and shipped out to the Ohio River were this stream improved; but I think that large deposits will have to be found to justify the erection of blast-furnaces depending upon the local supply. It would be quite in place that an ore of iron similar to the celebrated Scotch black-band ore should be found in this valley.

The three months of the year which would afford a scant supply of water for the locks might readily be tided over by the construction of a reservoir could a suitable location be found. This examination did not extend to cover this point.

The undetermined amount of excavation at each lock and dam, extent of the wing-walls, and price per cubic yard of dimension and rubble stone at each location, render any approximate estimate of the cost of the work impossible; but the nearness of the sandstone cliffs, and the character of the soil of the bottom-lands, would point fairly to a low price of construction.

The enormous quantity of coal in the hills fronting the river, and the ease with which it can be loaded in barges, the probable manufacturing of woods and wooden ware, the production of salt, and carriage of iron-ores, as well as the vast increase of merchandising which would follow this improvement, all seem to indicate that the necessary outlay would be remunerative and the work entirely successful.

I think this improvement ought to contemplate the carriage of such coal and iron barges as can be used upon the Mississippi River below Cairo at the present time. This would require, according to my information, barges of 150 feet in length, 25 feet beam, and 7½ feet draught. In order to conform to this rate, the depth of water upon the miter-sills of the proposed locks on the Guyandotte River should be increased to 7½ feet, and the works strengthened accordingly.

Guyandotte River.

Miles from Ohio River.	Name of place.	Elevation— Above low water of Ohio River at foot of shoal.	Elevation— Above low-tide of ocean at foot of shoal.	Fall.	Length.
		Feet.	*Feet.*	*Feet.*	*Feet.*
0	Ohio River	0.00	497.034	6.2	....
13	Rogers's Mill-dam	25.80	522.834	6.2	....
25½	Salt-Rock Dam	42.40	539.434	2.6	....
31¼	Falls in Guyandotte	52.40	549.434	3.6	....
34¼	Four-mile Shoal	59.20	556.234	3.6	1,200
41¾	Laurel Shoals	65.20	562.234	3.8	1,200
43½	Hatfield's Shoal	70.40	567.434	2.8	1,400
44¼	Shoal	74.40	571.434	1.2	500
47¼	Hamilton Shoals	76.00	573.034	4.0	2,500
49¾	Little Ugly Shoal	80.00	577.034	3.4	1,000
50¼	Shoal	83.60	580.634	2.0	400
54¼	Lambert's Mill-dam	87.20	584.234	3.6	....
57¾	Heart's Creek Shoal	91.60	588.634	2.4	1,000
60	Green Shoals	96.40	593.434	3.2	1,000
62	Muskrat Shoals	100.00	597.034	2.2	1,000
64	Big Creek Shoal	102.40	599.434	2.4	700
65¾	Shoal	105.00	602.634	2.2	800
66¼	...do	107.60	604.634	1.2	300
67¼	...do	108.80	605.834	2.4	1,000
69½	...do	111.20	608.234	1.8	1,000
70½	Godby's Lower Shoal	113.00	610.034	2.2	700
70¾	Godby's Upper Shoal	118.20	615.234	1.4	1,200
73¼	Tony's Shoal	120.40	617.434	2.0	1,000
74	Peck's Shoal	123.00	620.034	6.6	2,500
74¼	Peck's Mill-dam	129.60	626.634	3.6	....
75¾	Shoal	133.20	630.234	2.4	600
77¾	Buffalo Shoals	135.60	632.634	1.4	500
79	Shoal	140.80	638.634	2.2	2,100
80¼	Logan Shoal	143.60	640.634	3.2	2,600
81¼	Logan Court-House	147.76	644.794	......	....

2.—*Twelve Pole-River, West Virginia.*

Our preliminary survey of the Twelve-Pole River began at its mouth, a short distance above Ceredo, in Wayne County, West Virginia, and three miles east of the Kentucky State line.

Ascending the river, we find it flows in a tortuous course through the bottom-lands of the Ohio River for nearly three miles. Then, turning to the southeast, it enters the valley proper of the Twelve Pole. This valley is narrow and exceedingly crooked, the distance over which the survey extended to Wayne Court-House being, by the windings of the river, thirty-one and one-half miles, while in a right line from its mouth to Wayne Court-House the distance is but little more than fourteen miles.

The river divides into two branches a short distance south of Wayne Court-House, the discharge of water from each fork being nearly equal. I did not measure the separate flow of these branches, but estimated it from the appearance of the streams of water.

The course (say south 23° east) from the mouth of Twelve Pole to Wayne Court-House, continued some fifteen miles, brings us to a high ridge, stretching from the Guyandotte River on the east, to the Tug Fork of the Big Sandy River on the west, and on the north side of this ridge both forks of the Twelve Pole find their sources, which are but a few miles apart.

The bottom-lands of the Twelve-Pole Valley are narrow, and are bounded on either hand by a range of steep hills, occasionally broken by the tributary streams of the river. These hills continually increase in height as we ascend the river, and they, together with the bottom-lands, are largely covered with forest-trees.

The river-bed is from 60 to 125 feet in width, with alluvial banks of 20 to 30 feet in height to a level with the lands of the valley. The width at the top of the banks varies from 150 to 250 feet. The river flows over a bed of sand, with an occasional shoal of sandstone. At two points, however, the Falls of the Twelve Pole and at Wayne Court-House, (P. Workman's mill,) the river breaks through a solid stratum of sandstone, and both of its banks are of the same stable material. The river-bed and banks of that part which flows through the low-lying lands of the Ohio River are approximately of the same dimensions as those given above. The river banks are of sand and clayey earth, and apparently of unstable character, except where protected by the growth of the willow and various forest trees. They are also filled with craw-fish, and to what distance these drift from the water I am unable to say, but this point should be carefully determined at each location of a lock and dam.

The total fall of the river from Wayne Court-House to its mouth is 79.11 feet.

There are only two pools of any length: the first above Thorp's mill-dam, and the second that above the falls of Twelve Pole. Elsewhere the water is shallow and the declivity continuous.

The three mill-dams—Thorp's, Adkins's, and Workman's—present obstructions to the present use of the river, that of floating small rafts of timber into the Ohio. I was informed, however, that they presented no very great difficulty when the proper stage of water was chosen upon which to float out these rafts. All the river-banks are lined with forest-trees, which are carefully conserved for the stability they impart. Those only that are leaning can be objected to, as they would greatly endanger steam-tows, provided the navigation of the river could be rendered permanent. A judicious cutting away of limbs and cutting some of these trees would do away with this inconvenience, and not invite the present destruction of the river-banks. The removal of the mill-dams and leaning trees would doubtless facilitate the running of timber-floats out of the river, but I do not think that these removals would in any way tend to promote navigation from the mouth up stream. This opinion is based upon, first, the total fall for the length of the river; and, second, for a reason that becomes apparent as we proceed with the consideration of this subject. Therefore, the only improvement that I could recommend, giving even an apocryphal promise of satisfactory results, would be by means of slack-water navigation.

I have indicated upon the map and profile such points as seem to present strong natural positions for locks and dams. Careful examinations, with boring, can alone determine if these are really well taken, and also the foundations which it were better to adopt in each case.

The first three dams stand in the alluvial lands of the Ohio River. These will require pile-foundations. I have made the lift 8 feet. This is very high, when we consider the unstable nature of the banks, and the wandering habits of the craw-fish, which will render even the permanency of a low lift very problematical at these points. The remaining locks and dams can probably all be placed upon rock-foundations by excavations of from 8 to 12 feet. I would recommend that the superstructure of the first three, and all the remaining locks and dams, be of sandstone, of which there is great abundance all along the valley.

The river should generally be widened at the points where the locks and dams are located, until the rectangle of the weir considerably exceeds that of the river-bed and banks. An oblique weir would hardly be admissible between so narrow river-banks, with such great vertical rise, and the plan of widening the river should throw the locks, lock-walls, and both abutments quite out of the current, and away from the drift-wood. Long wing-walls, running into the bank from either abutment, would add much to the stability of the structure, especially when the walls can be so extended as to reach a stratum of bed-rock lying above high-water mark.

It is to be regretted that the lift is so unequal, as shown in the profile which I submit, and probably a more extended examination would remedy much of this difficulty.

At a distance of 3,000 feet up the Twelve-Pole River from its mouth, the bank between that and the Ohio River is very narrow. The Ohio River appears to be cutting its left bank all along near the point indicated, and there is probably a strip of from 8 to 10 feet yearly cut away. At this rate only a few years will be required to change the mouth of the Twelve-Pole so that it will empty into the Ohio at the point above mentioned.

I have endeavored to collect statistics of the business resources of this valley, but my efforts have not been very successful. This is to be regretted, as a full statement of the commercial interests to be served would seem a necessary adjunct to this report.

From observation, I infer that there are no agricultural products in excess of the wants of the inhabitants, nor do I think there ever will be, the lands being poorly adapted to farming purposes. I will, however, make an exception in regard to fruit-raising. The apple and peach crops are very abundant, and of excellent quality, from the small orchards which we saw to the larger ones of more favored localities, giving promise of a greater yield when no longer neglected. But this branch of agricultural industry could hardly, at least for a long time, assume a magnitude sufficient to warrant the expense attendant upon the construction of locks and dams.

The distance examined to the forks of Twelve-Pole does not reach the coal-fields of this river-valley, the first appearance of heavy veins of coal above water-level being some four miles further south. Slack-water navigation to the forks of Twelve Pole would not, therefore, aid in developing the coal-mines of this valley, nor would there be any coal-carriage over the improved navigation if it were made. At several points along the line of our examination, I noticed the "lean" ores of iron incident to this geological formation. The largest deposit that I saw was in the hillside over the left bank of the river near Pleasant Workman's mill. At an elevation of, say, 18 feet above the river-bed, and in a matrix of shale, is quite a heavy deposit of "kidney ore." This is in sight for, say, 2,000 feet along the hillside, and near the river. I do not think ores of iron in sufficient quantity to justify the erection of smelting-works have yet been found at any point in this valley, but a large quantity of ore would doubtless be mined and shipped out were a sufficient and practicable navigation provided.

The getting-out of timber and logs for sawing seems to be the paramount industry of this valley. To this all other pursuits are subordinate. G. G. Burgess, esq., of Wayne Court-House, estimates the value of the average yearly products of wood in the valley at $170,000. These logs and pieces of timber are fastened together in small floats, and are taken out into the Ohio River when the Twelve-Pole is sufficiently swollen with rains. I fail to see that this interest would be much benefited by a system of slack-water navigation. The manufacture of wooden wares of various kinds could be successfully carried on along this stream, and would prove a fruitful source of revenue if an improved river-navigation were practicable.

The abrupt character of the watershed of this river results in floods which are enormous compared with the ordinary flow of the river. The vertical rise is sometimes eighteen feet. A cross-section of this river taken at Wayne Court-House, September 12, 1874, computed by a liberal formula, makes the discharge 2.1 cubic feet of water per second. This quantity of water would probably no more than suffice for absorption, leakage, and evaporation, and would leave no water to fill the locks. This is probably a fair average flow of the river when not swollen by rains, and would, I should think, be a full average for six months of the year. Should the river be improved there would then exist a necessity for reservoirs of sufficient capacity to supply the necessary water for the locks for this length of time during each year. Whether natural and easy positions for the construction of these reservoirs exist, I am unable to say, my examination not being extended to cover this contingency. Whether this geological formation would hold water would likewise become an important element in the further investigation of this subject, and its solution rather falls without the province of the engineer.

In conclusion, I can see no present or prospective necessity for the execution of this work, nor do I think it practicable.

A. L. COX,
Assistant Engineer.

P 6.

SURVEY OF BIG SANDY RIVER, KENTUCKY.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, February 24, 1875.

GENERAL: The river and harbor bill, approved June 23, 1874, contained clauses directing the Secretary of War to cause examinations or surveys to be made at the following points:

"Big Sandy River, below Piketon, Ky."

"Big Sandy River, from its mouth to Piketon and Warfield, in Kentucky."

By your letter of July 3, 1874, the charge of these surveys was assigned to me. I at once placed the work in the hands of Mr. James E. Bell, assistant engineer, and I have the honor herewith to forward his report.

It will be seen from it that the Big Sandy proper is twenty-six miles in length, from Catlettsburg, at its mouth, to Louisa, at the junction of its two forks, and that Piketon, on the Louisa Fork, is eighty-six and one-half miles above Louisa, or one hundred and twelve and one-half miles above Catlettsburg, and that Warfield, on the Tug Fork, is thirty-five miles above Louisa, and sixty-one miles above Catlettsburg. The total length of the survey was one hundred and forty-seven and one-half miles.

The fall of the river is distributed as follows:

	Feet.
Piketon to Louisa via Louisa Fork	129.719
Warfield to Louisa via Tug Fork	61.184
Louisa to Catlettsburg via Big Sandy River	27.479

It is evident that the only feasible way of procuring a sufficient supply of water for navigation, and especially for a navigation by coal-barges, is to canalize the river by means of locks and dams. In doing this we at once have our choice of two methods—the French method recently invented, of movable dams, and the method in use on the Monongahela, Muskingum, Kentucky, and other rivers, of permanent dams. The first method is decidedly the better of the two where the natural navigation lasts for several months continuously; but its greater cost of establishment, and of maintenance, naturally causes the selection of the second method for rivers on which the total amount of navigation is not great. As the Big Sandy, at least at present, is decidedly a river of small navigation, I have chosen the method of permanent dams as the proper one under existing circumstances.

Assuming a lift of 10 feet, which experience on the Monongahela has shown to be the most serviceable lift for river-locks and dams, we obtain the following table:

	Distance.	Rise.	Locks and dams required.
	Miles.	*Feet.*	
Catlettsburg to Louisa	26.0	27.479	3
Louisa to Piketon	86.5	129 719	13
Catlettsburg to Piketon	112.5	161.198	16
Catlettsburg to Louisa	26.0	27.479	3
Louisa to Warfield	35.0	61.184	6
Catlettsburg to Warfield	61.0	88.663	9

It was impossible in the brief examination made during the survey to make detailed locations for the different locks and dams, but from the approximate locations that were made it was found that one-third of the dams would come on gravel, and the remainder on rock. This average will probably prove reasonably correct; if any change should result from a second examination for exact locations, it will be most likely to cause a decrease on the locations on gravel, and thus a decrease in the total cost.

In the following estimate no account is taken of the coffer-dam, as it is believed that by building in low water this expense would be trifling.

The size of lock has been fixed at 45 feet in width, and 200 feet in available length, as it is thought that a larger lock would be out of proportion to the available supply in low water. By "available length" is meant the distance between the chord of the upper miter-wall and the upper ends of the recesses of the lower gates. This is the full length that is available for the use of boats.

The average length of a dam will be 250 feet. The average height will be 15 feet, and the width of base 45 feet. The up-stream slope will be one on one and a half, and the down-stream slope one on three. The crib-work will be filled with riprap, and its upper slope will be sheathed with 4-inch planking, and its lower slope with 8-inch timbers.

ESTIMATE.

One river-lock with lift of 10 *feet*, 5 *feet on lower miter-sill*, 200 *feet of available length, and* 45 *feet width in the clear; rock foundation.*

	Cut-stone masonry.	Coursed rubble.	Uncoursed rubble.	Price.	Cost.
	Cubic yards.	*Cubic yards.*	*Cubic yards.*		
River-wall, inside face	507			$15 00	$7,605 00
River-wall, outside face		580		8 50	4,930 00
River-wall, coping	115			15 00	1,725 00
River-wall, backing			1,059	6 50	6,883 50
Land-wall, inside face	550			15 00	8,250 00
Land-wall, coping	112			15 00	1,680 00
Land-wall, backing			1,366	6 50	8,889 00
Miter-walls	120			15 00	1,800 00
Wing-wall, face		78		8 50	663 00
Wing-wall, coping	15			15 00	225 00
Wing-wall, backing			163	6 50	1,059 50
Rock-excavation, 3,000 cubic yards				2 00	6,000 00
Lock gates and wickets, 4 leaves				1,000 00	4,000 00
Lock-keeper's house					1,200 00
Total					54,910 00
Contingencies and engineering, 10 per cent					5,491 00
Total cost of lock					60,401 00

Gravel foundation.

When this kind of foundation is encountered, the lock should rest on a platform supported on piles and covered with 3 feet of concrete. Filtrations under the lock should be prevented by a liberal use of sheet-piling.

Masonry as previously estimated	$43,710 00
Masonry saved by using concrete, 200 cubic yards, at $10	2,000 00
Cost of masonry on concrete foundation	41,710 00

Foundation:		
731 piles, 12 feet long, at $4.50	$3,289 50	
Caps and stringers, 54,900 feet, board-measure, at $20	1,098 00	
Flooring, 63,000 feet, board-measure, at $30	1,890 00	
Transverse binders, 7,740 feet, board-measure, at $30	232 20	
Bolts and spikes, 25,000 pounds, at 6 cents	1,500 00	
Labor, capping piles and laying floor	800 00	
Concrete, 2,100 cubic yards, at $5	10,500 00	
Riprap, 700 cubic yards, at $1	700 00	
Gravel filling, 700 cubic yards, at 50 cents	350 00	
Gravel excavations, 5,000 cubic yards, at 30 cents	1,500 00	
Sheet-piling, 520 feet, at $4.20	2,184 00	
Total for foundation		24,043 70
Lock-gates and wickets		4,000 00
Lock-keeper's house		1,200 00
		70,953 70
Contingencies and engineering, 10 per cent		7,095 37
Total cost of lock		78,049 07

Timber dam.

The method of construction on which the estimate is made is the same as that now in use on the Monongahela. It would undoubtedly be better to build dams of stone, especially where rock foundation can be found; but such dams would be more expensive than timber dams, and therefore their consideration may be left to the future.

Rock foundation per running foot.

67 cubic feet of timber, at 25 cents	$16 75
336 feet, board-measure, sheathing, at $40	13 44
15 cubic yards riprap filling, at $1	15 00
Drift-bolts, spikes, &c	7 00
Gravel filling above dam, 3 cubic yards, at 50 cents	1 50
Total per running foot	53 69
Cost for 250 running feet	13,422 50

Cost of masonry abutment.

30 cubic yards concrete, at $5	$150 00	
190 cubic yards coursed rubble masonry, at $8.50	1,615 00	
925 cubic yards paving bank, at $2.50	2,312 50	
500 cubic yards grading bank, at 20 cents	100 00	
200 cubic yards riprap, at $1	200 00	
Cost of abutment		4,277 50
Cost of dam and abutment		17,699 00
Contingencies and engineering, 10 per cent		1,769 90
Total cost of dam and abutment		19,468 90

Gravel foundation per running foot.

Previous estimate, per running foot	53 69
2 rows of sheet-piling, at $4.20	8 40
1 pile per running foot in apron	5 00
6 cubic yards riprap in apron, at $1	6 00
Total per running foot	73 09
Cost of 250 running feet	18,272 50

Cost of masonry abutment.

Cost as per previous estimate	$4,277 50	
12 piles, at $5	60 00	
125 sheeting-piles, at $4.20	525 00	
Cost of abutment		4,862 50
Cost of dam and abutment		23,135 00
Contingencies and engineering, 10 per cent		2,313 50
Total cost of dam and abutment		25,448 50

GENERAL ESTIMATE.

The total number of locks required in order to improve the main river and both forks will be as follows:

Catlettsburgh to Piketon	16
Louisa to Warfield	6
Total	22

Assuming that one-third of these will be on gravel, we have the following general estimate:

7 locks on gravel, at $78,049	$546,343
7 dams on gravel, at $25,449	178,143
15 locks on rock, at $60,401	906,015
15 dams on rock, at $19,469	292,035
Total for 22 locks and dams	1,922,536
Average for 1 lock and dam	87,388

Mr. Bell's report shows that in many places the bed of the river is full of large bowlders that should be removed. It is also full of snags, and the banks are encumbered with inclining trees. A good work can undoubtedly be done by removing these bowlders and snags, and cutting down the inclining trees. The total cost of this work will not be great, but it is quite indeterminate. The bowlders, except one large one, one mile above Prestonsburgh, called the Ball-Alley Rock, can be lifted out of the channel and deposited on the shores by the large grapple used on the Ohio and the Great Kanawha. The Ball-Alley Rock itself can be so removed after a few blasts have been put in.

If Congress should be unwilling to appropriate sufficient money for the construction of a complete system of slack-water, or if money were only appropriated for one or two locks, it would still be a very great advantage to navigation to have the bowlders and snags removed. The stage in the river is favorable for this work during about four months in the year.

I therefore estimate for two parties—one to remove snags, and the other to take the large grapple belonging to the Government and remove rocks. Each party should have a crane-boat and a small steamboat.

ESTIMATE FOR REMOVING OBSTRUCTIONS.

One party with steamboat and crane-boat per month	$1,600
One party for four months	6,400
Two parties for four months	12,800
Inspection and contingencies	2,200
Total for removing obstructions	15,000

I hardly think that this sum would remove all the obstructions, but it would probably remove the greater part of those in the bed of the river, and give means for making a more careful estimate for the following season. I think that this sum can be judiciously expended during the coming year, independent of any sum that may be allotted for locks and dams.

Fourteen sheets of map with profile accompany this report.

Respectfully submitted.

WM. E. MERRILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

REPORT OF MR. JAMES E. BELL, ASSISTANT ENGINEER.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, February 22, 1875.

COLONEL: I have the honor to submit the following report on the survey of the Big Sandy River. This stream is, for convenience, divided into three parts:

First. The Big Sandy River from Catlettsburg to Louisa, Ky.
Second. The Louisa Fork from Louisa to Piketon, Ky.
Third. The Tug Fork from Louisa to Warfield, Ky.

BIG SANDY RIVER.

The Big Sandy River is formed by the confluence of the Louisa and the Tug Forks, twenty-six miles from its mouth, opposite the town of Louisa, Lawrence County, Ky., and it is the dividing line between the States of Kentucky and West Virginia. It flows in a northwesterly direction, through a narrow valley, confined between rocky hills from 600 to 2,300 feet apart, and empties into the Ohio at Catlettsburg, Ky. The bordering hills are broken nearly every mile by streams which have their sources from two to fifty miles distant. The average width of this part of the river is 300 feet. It is to a great extent shallow, but in many places deep pools with rocky bottoms are found. The bottom-lands, varying in width, are about 50 feet above low-water mark and not subject to inundations except in extreme cases. The banks are in many places clear of trees, and except where the rocky hills immediately border the river they are composed of sand so fine and uniform in composition as to be easily washed away by the currents. The erosive action of this river during floods washes the sand from the roots of the trees to such an extent that they often become so inclined as to obstruct navigation. An examination was made a few years ago by boring into the river-bed, and rock from 8 to 20 feet below the suface of low water was found throughout the entire length of the river, except at its mouth. The natural bed of this stream is covered with sand, a deposit due, no doubt, to the large quantities of this material constantly being carried by the small rills into the various tributaries; thence it is brought into the river, and eventually it finds its way to the Ohio. The numerous bars found at the mouths of the branches are constantly being carried from place to place by the successive rises in the river.

This stream is crooked like other mountain-rivers, and its average fall is 1.05 feet per mile. The number of inclining trees is 2,249, and the number of snags 1,396.

LOUISA FORK.

The Louisa Fork is the principal branch of the Big Sandy River, and it rises beyond the Cumberland Mountains in the table-lands of the southwestern part of Virginia, at an elevation of 1,500 feet above tide-water. It flows, like the main river, in a northwesterly direction through a narrow valley. The fountain-head, being so far south, gives the river an advantage over northern streams in having but little ice, a feature of considerable importance to those interested in its navigation. In ascending the river the hills increase in height. In some places the banks are composed of rock; in others of sand and clay. Where they are of the latter material, the slopes are uniform. The bottom-lands, like those of the main river, are above ordinary high-water mark. There are many large bowlders in the river which have rolled from the bordering hills, and are obstructions which ought to be removed. The peculiar feature of this fork is the great number of rock-bars, which are doubtless due to the fact that its steep slope causes a velocity in the current so great as to prevent the sand from lodging. These rock-bars have only a few inches of water on them during low stages, while at the head and foot are pools varying in depth from 6 to 12 feet. The average fall from Piketon to Louisa, Ky., is 1.49 feet per mile, and the average width is 200 feet. The number of inclining trees is 7,656, and the number of snags 3,397.

TUG FORK.

The Tug Fork rises in the mountains of McDowell County, West Virginia, and flows in a northwesterly direction, forming, with the Louisa Fork, the Big Sandy River. It has the same general features as the Louisa Fork. The hills come nearer the river, and consequently the bottom-lands are not so wide. This fork, as far up as the Falls of Tug, is shallow, crooked, and narrow; so shallow during low water as to render navigation impossible; but above the falls its character changes, and it becomes a succession of pools separated by rock-bars. The hills are very steep, exposing the rocky materials of which they are mostly composed. The banks are alternately of rock and of sand, but, when formed of the latter material, they have been but slightly cut away by the river on account of the protection afforded by trees and plants. The average width of this fork is 180 feet, and the average fall from Louisa to Warfield, Ky., is 1.75 feet per mile. The number of inclining trees is 2,822, and the number of snags is 801.

GENERAL REMARKS.

All these streams are fed almost entirely by mountain-springs, which, when the branches near the mouth are dried up, continue their usual supply, and thus become the main sustenance of the river during low water. The Big Sandy River is the only outlet for a very productive country, rich in both agricultural and mineral wealth, yet it presents serious obstacles to the transportation of these productions to market. It is unnavigable in low water, and even in high water it is dangerous to navigation on account of its velocity and its sharp bends. On the Tug Fork these difficulties are increased by the number of leaning trees which project into the narrow channel.

The mines that were formerly worked on these forks were located at points where the river is shallow, so that boats could not be loaded during low water and held for a rise. The want of proper landing-places and the disasters and resulting loss incurred in trying to get coal to market have compelled the abandonment of work on all the mines, except those that supply the limited local demand.

The following statistics of the Big Sandy Valley have been prepared by Judge M. J. Ferguson, of Louisa, and will give some idea of the exports of this section:

"This table, compiled for the year ending July 1, 1870, embraces only that portion of the valley which now finds its only outlet by the river to the different markets.

"*Articles exported.*

	Value.
"Saw-logs, sawed lumber, and fencing-posts	$550,000
"Staves and spoke-timber	80,000
"Tan-bark	75,000
"Keg-timber	8,000
"Hoop-poles	25,000
"Barges and small craft	45,000
"Fruit	40,000
"Feathers, bees-wax, ginseng, tallow, hides, poultry, eggs, butter, flax-seed, rags, and produce of country stores	165,000
"Wheat and corn	50,000
"Potatoes	6,000
"Live stock	175,000
	1,219,000

"This estimate was made from memoranda collected from merchants, timber-dealers, and common carriers, and has been recently revised upon the following basis of values:

"The timber is valued at 12½ cents per cubic foot, and a fleet of saw-logs is estimated at an average value of $3,500 in the Cincinnati market, the tan-bark at $15 per cord, and the staves at $24 per thousand.

"Barges and other craft are valued at $2 per linear foot. The item $165,000 from country stores is ascertained by counting the number at 110, and their average export at $1,500. This is believed to be much under the true value. Previous to the year 1868, the corn and wheat produced were used almost entirely for home consumption, but since that time the export of these grains has steadily increased, until now the gross export would probably double the estimate in the above table.

"There has been much difficulty in estimating the value of live stock, and it is believed that this item is very low. The general exports of this valley have, since the year 1866, increased more than 25 per cent. annually, and some of the smaller products at a much greater rate.

"For example, in one county situated near the mouth of the river, the sale of eggs in the year 1866 did not exceed $1,000, while in the year 1870 it amounted to about $12,000. Any general improvement of the Big Sandy River would secure for it the exports that now go overland."

Judge Ferguson assured me that the exports for the year ending September 1, 1874, would not materially differ from those given in the above table, and that, although there would be changes in detail, the total would remain about the same. It is estimated that the steamboats and the push-boats carry 30,000 people and about 30,000 tons of freight annually up and down this river during the season of navigation. The census gives 80,000 as the population of those counties that use this valley as an outlet to market.

The steamboat Fleetwing, 117 feet in length and drawing 30 inches, navigates this river as far as Louisa during nine months, and as far as Piketon during five months in each year. The back-water of the Ohio River gives sufficient depth of water for navigation to some distance above Louisa.

The river was gauged during this survey with the following results: On the Louisa Fork, at low water, the discharge was found to be as follows: At Beck's Shoal, 32.6 cubic feet per second; near Big Shoal Branch, 60.07 cubic feet per second. On the Tug Fork, when the river was nearly at low water but rising, the discharge near Lick Shoal was 138 cubic feet per second. The discharge of the Big Sandy River at its mouth was found to be 753.3 cubic feet per second, the river being near low water but rising. It was with the greatest difficulty that our boat, drawing only 5 inches, could get over the shoals and bars when descending the river between Piketon and Louisa, The Big Sandy and its branches drain an area of 4,600 square miles, equaling in extent about one-twelfth of the State of Kentucky. This river and its forks rise during certain seasons very suddenly, often to the height of 50 feet, and fall nearly as quickly. Each creek has a valley and bottom-lands, similar to those of the stream into which it empties, but correspondingly less in extent.

The principal tributaries of the main river and of its two forks, with their approximate lengths, are as follows:

Tributaries of the Big Sandy River.

	Miles.
Blaine Creek	40
White Creek	9
Bear Creek	20

Tributaries of the Louisa Fork.

Lick Branch	12
George's Creek	15
Tom's Creek	20
Griffith's Creek	9
Nat's Creek	9
Greasey Creek	9
Paint Creek	60
Little Paint Creek	15
Beaver Creek	30
John's Creek	75
Middle Creek	30
Mud Creek	20
Bull Creek	10
Ivy Creek	10

Tributaries of the Tug Fork.

Mill Creek	20
Rock Castle Creek	30
Jenny's Creek	9
Elk Creek	10
Marrow-Bone Creek	15

The bottom-lands are almost all above ordinary high-water mark, and are very fertile. The grasses grow spontaneously, and are of excellent quality. This country generally yields a sure crop of various kinds of fruit. Corn is the principal grain produced, but as there is no demand for it, only enough is raised for home consumption.

The hills are covered with dense forests of valuable timber, including walnut, ash, maple, poplar, oak, white walnut, chestnut, and yellow pine, which furnish the principal supply of wood to the steamboat-builders and furniture-makers of Cincinnati. This timber, the only considerable export, goes out at flood-time and gluts its own market, thereby barely paying the labor of preparing and transporting it. The want of regular communication with a market has prevented the investment of manufacturing capital in this valley; and as the present condition of the river has made the money already invested in coal-lands along its banks unproductive, there is no demand for labor except in the lumber-trade.

Prof. D. D. Owen, in his report on the geology of the State of Kentucky, states that the best exposure he has seen of the coal-measures of the Big Sandy Valley is in the vicinity of Prestonsburgh. In Lawrence County, south of Louisa, on the Big Sandy River, he found six or seven beds of coal, measuring in the ascending order from 2 to 4 feet in thickness, and above these a bed of cannel-coal. In Johnson, Floyd, and other counties, he found six or seven beds. Near the dividing-line of Floyd and Pike Counties, he found numerous beds of coal, the main vein consisting of three strata, of the united thickness of 7½ to 8 feet. The analysis of the coal of this valley gives from 30 to 35 per cent. of volatile matter, and from 64 to 65 per cent. of carbon. The percentage of ashes is very small. The greater the amount of carbon and the smaller the quantity of ashes, the better the coal for manufacturing purposes.

The report of the commissioner of emigration of West Virginia states that beds of hematites, oxides, and peroxides of iron are found in the great coal-regions of the Kanawha and Big Sandy Valleys. In many places, iron-ore alternates with coal and lime.

I am enabled, by the kindness of Prof. N. S. Shaler, superintendent of the geological survey of the State of Kentucky to present his personal observations of the geological features of this valley in the following report:

"NEWPORT, KY., *January* 1, 1875.

"MY DEAR SIR: It gives me great pleasure to answer your questions concerning the mineral resources of the Big Sandy, or Chatterawha River. Unfortunately the geological survey has not yet been carried far enough in that valley to enable me to speak in much detail concerning its resources, but enough is determined to warrant me in the general statements contained in the following brief report. These statements are based on my personal observations, so far as the valley of the principal stream is concerned; for the Tug Fork branch I have the statements of my esteemed associate, Mr. A. R. Crandall, principal geological assistant of the Kentucky survey.

"Very sincerely yours,

"N. S. SHALER,
"*Superintendent of the Kentucky Survey.*

"J. E. BELL, *Civil Engineer.*

"GEOLOGICAL RESOURCES OF THE BIG SANDY VALLEY.

"*Mineral resources.*

"Every part of this valley which has been explored by the Kentucky survey lies in the rocks of the Carboniferous age, or at least above the level of the base of the subcarboniferous limestone. Its mineral stores are therefore limited to the materials found within these geological bounds. Coal, iron, and salt, together with building-stone and fire-clay, are the products that may be sought here. The coal-beds of this valley are doubtless, in part, the western extension of the beds of the Kanawha Valley, and therefore in a measure to be judged by those well-known sources of coal. They all appear to belong to the lower division of the coal-series, and are contained in the series of beds lying within less than 900 feet of the top of the subcarboniferous limestone. The following general section,* made up from the researches of Messrs. A. R. Crandall and P. N. Moore, in Greenup, Carter, Boyd, and Lawrence Counties, the latter two lying on the Big Sandy River, throws important light on the question of the occurrence of coal in this section. Going southward along the Big Sandy and its tributaries, the upper coals on this section seem to become of less consequence, while the lower coals, or some of them at least, seem to increase in thickness and to improve in quality. One of these coals, probably the Turkey Lick, or No. 3, in Greenup and Carter Counties, becomes the excellent coal at Peach Orchard, and seems to retain its quality over a wide area. At Peach Orchard, we have the following section† in the old mines at that point. This coal was for many years mined and shipped in large quantities, and commanded a high price in the Cincinnati market. Although there is some waste material in working this coal, it can be well and cheaply mined, and only needs the betterment of the water-transportation to give it the basis for profitable working.

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*See Fig. 1 on page 764. †See Fig. 2 on page 764.

Fig. 1.

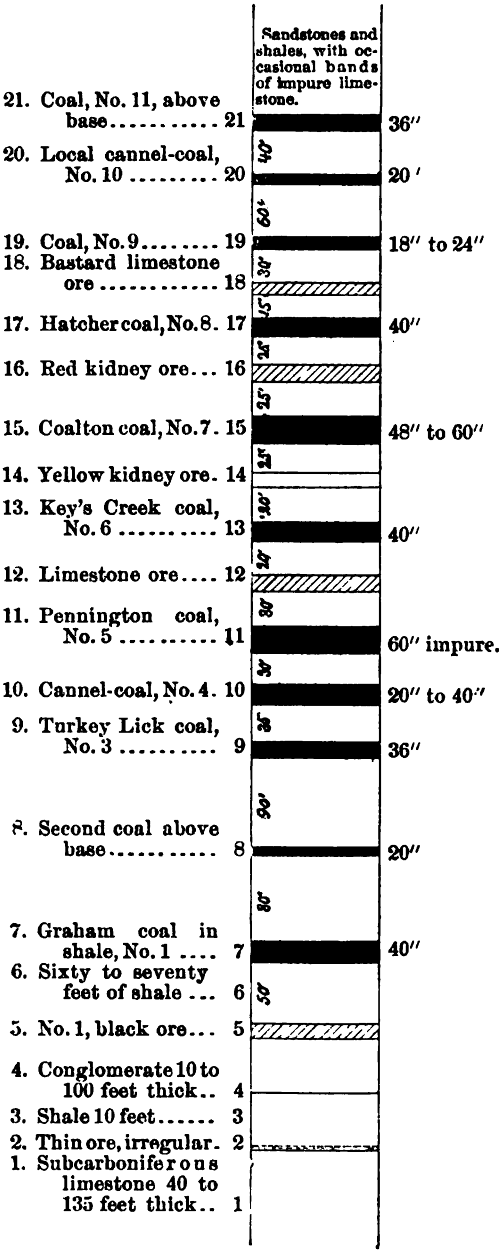
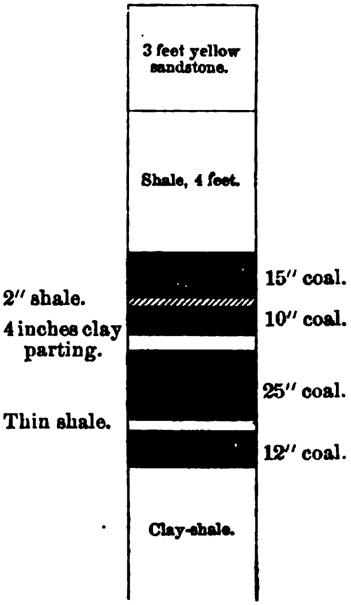

Sandstones and shales, with occasional bands of impure limestone.
21. Coal, No. 11, above base............ 21
36"
40'
20. Local cannel-coal, No. 10 20
20'
60'
19. Coal, No. 9......... 19
18" to 24"
30'
18. Bastard limestone ore............. 18
15'
17. Hatcher coal, No. 8. 17
40"
25'
16. Red kidney ore... 16
25'
15. Coalton coal, No. 7. 15
48" to 60"
25'
14. Yellow kidney ore. 14
30'
13. Key's Creek coal, No. 6 13
40"
20'
12. Limestone ore.... 12
80'
11. Pennington coal, No. 5 11
60" impure.
30'
10. Cannel-coal, No. 4. 10
20" to 40"
35'
9. Turkey Lick coal, No. 3 9
36"
90'
8. Second coal above base........... 8
20"
80'
7. Graham coal in shale, No. 1 7
40"
6. Sixty to seventy feet of shale ... 6
50'
5. No. 1, black ore... 5
4. Conglomerate 10 to 100 feet thick.. 4
3. Shale 10 feet...... 3
2. Thin ore, irregular. 2
1. Subcarboniferous limestone 40 to 135 feet thick.. 1

Fig. 2.



"This same coal extends over a very broad district, without much variation in character. There are also one or two other workable coals opened in this neighborhood. From Peach Orchard to Prestonsburgh, we are in continual contact with what seems to be Graham or lower coal of the series; and it seems to run from 30 to 36 inches of clear coal of good quality. Where it is exposed near the first ford, below Prestonsburgh, it shows about 3 feet of coal of remarkable evenness, with a good exposure for mining. Opposite Prestonsburgh, what seems to be the same coal, shows, in a trial opening, 40 inches of clean coal, without any parting, in an admirable position for working. I have not examined the main stream above this point, but am assured by Mr. Evan Jones, an experienced Welsh miner, who has spent many years in this neighborhood, that this coal continues to improve in thickness and quality for some miles above Prestonsburgh. The same series of coals extend up the Tug Fork of the Big Sandy River. At Warfield the coal just described as occurring at Prestonsburgh is five feet in thickness, with but one inch and a half of parting. Four and a half feet of this thickness is of excellent quality, the lower six inches being inferior, but fit for neighborhood use and for making salt. This is an admirable bed of coal, and is as thick as is necessary for the most economical working. Sixty feet above this bed there is another not opened up, but apparently thin. At about 170 feet above the lowest bed is another, which Mr. Crandall considers the same as the Peach Orchard coal. At about 280 feet above No. 1 there occurs a splint-coal about 3 feet thick. The value of the last-named coal is not known to me. Little has been done to open other beds, as the lowest of these coals is above high water, over most of the area examined. It is evident, even in the undeveloped state of the beds, that we have here a coal-section of remarkable richness, and the amount of country underlaid by them is so great that they would supply the whole demand of the Ohio Valley for centuries. The iron ores of this valley seem to be far less numerous than those in the valley of the Little Sandy River; in fact, the geological survey has not yet encountered ores of sufficient richness and abundance to warrant the erection of furnaces. The salt-wells of this valley seem destined to play an important part in its industry. The supply of brine is practically inexhaustible, and they are sure of fuel from the lower grades of coal, at about the actual cost of mining. From the few facts now at hand, it is evident that in this valley the supply of good steam, house, and coking coals will be very great for centuries to come.

"A little consideration of a map will show that with this stream properly locked and dammed, these coals will be nearer by continuous water-navigation to the markets of Cincinnati than any coal now brought to them. Moreover, when barges are in the Ohio River at Catlettsburgh they are already past the most serious dangers which now menace boats in their voyage from the mines of Pennsylvania and West Virginia to the markets of the Lower Ohio and Mississippi Rivers. Even counting a reasonable rate for lockage, it seems to me that coal can be brought from this river to Cincinnati for a much less sum than it costs to bring it from Pittsburgh. I have had the estimate made by one gentleman well acquainted with the business, and it shows that there would be a net advantage of nearly one cent a bushel over the coals from the Upper Ohio. Be this as it may, the chance of greatly increasing the coal area accessible to the Ohio cities will well repay the expenditure of money in the improvement of this river. It may not be amiss to say that I have examined the building-stone, with reference to its use for locks and dams, and am satisfied that it is perfectly fit for such use. I have also satisfied myself that it will be possible, with riprap and willow-tree planting, to secure the wings of the dams against washing. I would suggest that the wings of the dams be put in a year sooner than the dams, and the whole ground about them be closely planted with willows. Careful study of the action of willows in such positions has shown me the efficacy of the precaution.

"N. S. SHALER."

The only feasible improvement for the navigation of this river, owing to the limited supply of water during several months of the year, is by means of locks and dams. The various cross-sections where sites have been selected, except at the mouth, show favorably for the erection of locks and dams, there being always rock-formations on one side and on the bottom of the river, thus giving good foundations for the lock and the main portion of the dam, while the bank at one end of the dam only will have to be protected against wash. The fall of 157.2 feet between Piketon and Catlettsburg requires the erection of 16 locks of 10 feet lift, while the fall of 61.2 feet between Warfield and Louisa, Ky., takes 6 locks of the same lift. These locks should be 200 feet long and 45 feet wide, with 5 feet of water on lower miter-sill. The average length of the dams will be about 250 feet.

There are 14 maps accompanying this report, whose horizontal scale is 1 inch to 1,000 feet, while the vertical scale is 1 inch to 6 feet.

Respectfully, your obedient servant,

JAS. E. BELL.

Bvt. Col. WM. E. MERRILL,
Major Corps of Engineers.

Big Sandy River.

Miles from Catlettsburg.	Name.	Elevation above low water, Ohio River, at Catlettsburg.	Elevation above tide-water of ocean.	Rise in feet.	Length in feet.	Remarks.
	Catlettsburg, Ky	0	488. 362			Extreme high-water mark of 1865 is 2.93 feet above door-sill of Mr. Joseph Newburg's store, on Front street. Its elevation above tide-water is 550.362 feet, or 62 feet above low-water mark in the Ohio River. Catlettsburg is in Kentucky, at the mouth of Big Sandy River, and it contains, according to the last census, 3,183 inhabitants. The principal business of this town is to furnish supplies for the Big Sandy Valley. The manufacturing interests are of no great consequence. The bottom of the Big Sandy River, at the time of this survey, was 7 feet above low-water mark in the Ohio.
1. 5	Foot of English Hills, a large sand-bar opposite same.	10. 81			1, 000	Very steep and rugged hills on the West Virginia side of the river. Depth of water at foot of bar, 1.5 feet. Depth of water at head of bar, 1 foot.
5	Kaeser Rocks	12. 80				Large rocks bordering the river on the Virginia shore.
7	Nigger-head Rocks	13. 25				Immense blocks of stones have rolled from the hills near by and lodged in the river on the Virginia shore.
	Pool near rocks	13. 30			500	Average depth, 9.6 feet.
7. 8	White Creek Landing, W. Va.	13. 50				A small place, of no importance, containing a store and few inhabitants.
9. 5	Pool above Pritchard's Branch.	13. 89			800	Depth at head, 3.2 feet; at foot, 3.2 feet.
10. 5	Pool	14. 16			2, 000	Average depth, 5 feet; rock bottom.
11. 5	Pool	15. 00			1, 500	Average depth, 6 feet; rock bottom.
13	Bloomer Bar	15. 836			2, 640	Depth of water at head, 2.75 feet; at foot, 1 foot; average, 1.5 feet. This bar is composed entirely of sand, and is an obstacle to navigation when the water becomes low. There is at all times a bar at this place.
13½	Turnam's Ferry	16. 053				A ford across the river at this place. There are a few houses on the Virginia shore. This point is about the center of Round Bottom, a high and well-cultivated bottom-land, covered with water only during extreme floods.
14. 6	Pool near Rush Creek.	16. 50			1, 200	Rock bottom; average depth, 8.1 feet.
15. 8	Rove Creek Bar	19. 75			1, 200	Depth at head of bar, 2.43 feet; at foot, 1 foot.
17. 25	Dean Bend	21. 20				There is a saw-mill at this place; Virginia side hilly, Kentucky side high; cultivated bottom-lands.
25. 3	Pool opposite Hughes's Branch.	27. 60			1, 200	Average depth, 4 feet.
26	Louisa, Ky., county-seat of Lawrence County.	27. 479				Situated upon a level bottom-land above the high water of the river. Contains about 2,046 inhabitants. Has one flouring-mill and one steam saw-mill. This is about the only manufacturing that is carried on here. The town is well laid out, and has a tidy appearance.
25	Cassville, W. Va					Opposite Louisa. There seems to be no business here; it is a small place, containing about 500 inhabitants. The river and its forks are fordable at this place.

Big Sandy River, Louisa Fork.

Miles from Louisa.	Name.	Elevation above low water, Ohio River, at Catlettsburg.	Elevation above tide-water of ocean.	Rise in feet.	Length in feet.	Remarks.
	Low water at Louisa..	27.479	515.841	......	......	
5.0	Five-Mile Shoal.......	31.900	520.262	......	......	Channel-way of the river is contracted by means of large stones and gravel. Henry Cochran's coal-mines are near this shoal, from which an excellent quality of coal is taken to supply Louisa.
		32.420	520.782	0.52	200	
5.9	Twist and Wind Shoals	36.000	524.362	......	......	Rocky banks on right.
		37.807	526.169	1.807	350	
7.25	Twin Brothers Shoal..	38.600	526.962	......	......	
		39.000	527.362	0.40	1,100	
8.2	Devil's Nubbins Bend	....	....	......	......	Banks slope gradually: rocky on right rock bottom.
	Pool	....	....	......	500	Average depth, 7 feet.
9	Contrary Shoal.........	....	....	......	100	A small shoal.
	Pool	....	....	......	2,000	Average depth, 5 feet.
11.5	Foot of Buffalo Rock Shoal.	42.512	530.874	......	......	Rock bottom; rock bar on right.
	Head of Buffalo Rock Shoal.	43.312	531.674	0.80	500	
13	Fish-Trap Shoal, foot..	44.610	532.972	......	......	
	Fish-Trap Shoal, head.	46.110	534.472	1.50	800	
14.57	George's Creek Post-Office, Ky.	....	....	......	......	A small place, containing about 150 inhabitants, being situated in the bend of the river, upon a high bottom-land.
17	Peach Orchard, Ky....	....	....	......	......	Situated upon the right bank of this river was formerly a place of some consequence, on account of the coal mined there. The coal taken from these mines is said to be of an excellent quality. This place has about 200 inhabitants, and has a very dilapidated look. There is no trade. The hills back of this place are very steep and rugged.
17.25	Log Shoals............	51.500	539.862	......	......	
		53.000	541.362	1.50	500	
17.5	Brown's Defeat Shoals.	54.317	542.679	......	......	
		55.817	544.179	1.50	900	
19.8	Graves's Shoals.......	56.300	544.662	......	......	
		58.850	547.212	2.55	900	
20.25	Bumblebee Shoal......	59.800	548.162	......	......	
		61.346	549.708	1.546	200	
20.75	Jos. Border's Ripple...	61.346	549.708	......	......	
		62.446	550.808	1.10	900	
22.1	Kiah Border's Ripple .	63.610	551.972	......	......	
		64.000	552.362	0.390	150	
22.3	Lost Creek Shoal......	64.253	552.615	......	......	River is filled with cobble-stones. Outcropping of shale on left bank. Right bank sandy. Average depth of pool, 8 feet.
		64.750	553.112	0.497	400	
	Pool	....	....	......	2,000	
22.6	Yocca Shoal	64.750	553.112	......	......	
		64.900	553.262	0.15	175	
23	Murray Shoal.........	64.900	553.262	......	......	
		65.100	553.462	0.20	175	
23.6	Chestnut Creek Shoal.	65.254	553.616	......	......	
		66.150	554.512	0.890	200	
24.3	Jos. Davis's Shoal.....	66.303	554.665	......	......	
		67.651	556.013	1.348	150	
25.2	Little White House Shoal.	67.651	556.013	......	......	
		69.866	558.228	2.215	700	
26	Big White House Shoal.	69.866	558.228	......	......	
		73.701	562.063	3.835	1,000	
27	Red House Shoal......	74.551	562.913	......	......	
		74.715	563.077	0.164	475	
28	Wild Goose Shoal.....	75.591	563.953	......	......	
		76.691	565.053	1.10	600	
28.25	Ward's Shoal	77.165	565.525	......	......	
		78.122	566.484	0.957	300	
31	Greasy Shoal..........	78.710	567.072	......	......	
		82.380	570.742	3.67	1,000	
31.5	Jas. Preston's Ripple..	82.380	570.742	......	......	
		82.978	571.340	0.598	550	
31.7	Wm. Preston's Ripple	82.978	571.340	......	......	
		83.923	572.285	0.945	550	

Big Sandy River, Louisa Fork.

Miles from Louisa.	Name.	Elevation above low water, Ohio River, at Catlettsburgh.	Elevation above tide-water of ocean.	Rise in feet.	Length in feet.	Remarks.
33.5	Buffalo Shoal	84.091	572.453	......	......	Rock ledge on right.
		88.310	576.672	4.219	3,600	Left bank sandy; bottom rocky.
36	Paint Creek	....	....	......	......	Paintville, the county-seat of Johnson County, is situated on this creek about one mile from its mouth; population, according to last census, 3,961; town compactly built; there is no manufacturing here.
37.6	Hell-Gate Shoal	88.801	577.163	......	......	
		90.804	579.166	2.003	175	
38.25	Sherman Shoal	90.804	579.166	......	......	
		91.804	580.166	1.000	350	
42.15	Ennox Auxier Shoal	93.942	582.304	......	......	
		94.541	582.903	0.599	500	
45.25	Hagar Shoals	96.760	585.122	......	......	
		99.417	587.779	2.657	850	
45.3	Wireman Shoal	100.050	588.412	......	......	
		102.037	590.399	1.987	800	
48	Moody George Shoal	103.115	591.477	......	......	
		104.919	593.281	1.804	550	
50.6	Abbot's Shoal	105.447	593.809	......	......	Left bank very rocky.
		107.516	595.878	2.069	600	
52.15	Prestonsburgh Kentucky Shoal.	....	....	......	......	The county-seat of Floyd County, according to the census, contains 1,743 inhabitants; there are only a saw-mill and a few stores that do all the business of this place; the houses are in a dilapidated condition.
52.18	Town Shoal	108.143	596.505	......	......	
		109.475	597.837	1.332	750	
59.10	Shoal	117.521	605.883	1.000	250	
61.5	Hawes's Ford Shoal	119.846	608.208	......	......	
		123.390	611.752	3.544	300	
63.6	Welt Shoal	126.20	614.562	......	......	
		127.165	615.527	0.965	350	
64.4	Cecil Shoal	128.095	616.457	......	......	
		129.335	617.697	1.240	500	
64.8	Prater Shoal	129.335	617.697	......	......	
		130.300	618.662	0.965	350	
66	Davidson's Shoal	130.452	618.814	......	......	
		131.900	620.262	1.448	600	
67.2	Ivy Shoal	133.374	621.736	......	......	
		134.227	622.589	0.853	400	
68.3	Stratton Shoal	134.830	623.192	......	......	
		137.708	626.070	2.878	800	
71	Jack Stratton Shoal	137.708	626.070	......	......	
		138.847	627.209	1.139	350	
72.19	Lanesville Post-Office, Ky.	....	....	......	......	This is only a store where the mail is kept.
73.48	Town of Mud	....	....	......	......	This is situated at the mouth of Mud Creek, and contains a few houses; population about 150.
73.95	Grimes's Shoal, foot	139.826	628.198	......	......	
	Grimes's Shoal, head	141.643	630.005	1.817	250	
74.75	Industry, Ky	....	....	......	......	Was formerly a place of some importance, but since the mines near by have not been worked it has dwindled down to about 10 inhabitants. An excellent quality of coal was mined here.
76	Mars Shoal	143.396	631.758	......	......	
		145.280	633.642	1.884	700	
83.8	Long Shoal, foot	153.702	642.064	......	......	
	Long Shoal, head	157.740	646.102	4.038	3,000	
86.18	Shoal near Piketon	160.681	649.143	......	......	
		161.198	649.560	0.417	400	
86.5	Piketon, Ky., elevation of—					County-seat of Pike County; contains 1,949 inhabitants, (census returns.) This is a well-built and industrious town. There are no manufacturing interests here. The inhabitants are mostly engaged in exporting timber to the market on the Ohio River.
	Low-water mark	161.198	649.560	......	......	
	High-water mark	212.959	701.321	......	......	

Big Sandy River, Tug Fork.

Miles from Louisa.	Name.	Elevation above low water, Ohio River, at Catlettsburgh.	Elevation above tide-water of ocean.	Rise in feet.	Length in feet.	Remarks.
	Low water at Louisa..	27. 479	515. 841	......	......	
4.3	Shoals near Vinson's Creek.	38. 278	526. 640	......	......	
		39. 722	528. 084	1. 444	600	
6.4	Mulberry Shoal.......	41. 250	529. 612	......	......	
		42. 256	530. 618	1. 006	300	
7.1	Donathan Shoal, foot..	42. 800	531. 162	......	......	
	Donathan Shoal, head.	43. 305	531. 667	0. 505	200	
11	Falls of Tug, foot	46. 588	534. 950	......	......	These falls are at the mouth of Rock Castle Creek. The bed is a dike of trap-rock extending quite across the river, so hard as to remain, while the softer rock for a considerable distance up stream has been washed out to a depth many feet lower than this dam. This portion of the river is not silted up, but is one of the deepest pools in this fork.
	Falls of Tug, head.....	50. 091	538. 453	3. 503	500	
13.9	Copley Shoal..........	52. 557	540. 919	......	......	
		55. 417	543. 779	2. 860	1. 200	
16.8	Winding Shoal, foot...	56. 965	545. 327	......	......	
	Winding Shoal, head ..	59. 070	547. 432	2. 105	600	
17.8	Blakenship Shoal, foot.	60. 625	548. 987	......	......	
	Blakenship Shoal, head	61. 791	550. 153	1. 166	400	
19.75	Double Shoal..........	62. 239	550. 601	......	......	
		64. 639	553. 001	2. 400	900	
21.15	Stansberry Shoals.....	65. 315	553. 677	......	......	
		66. 114	554. 476	799	350	
23.5	Bull Shoal	68. 130	556. 492	......	......	
		70. 682	559. 044	2. 552	700	
24	Turkey Shoal.........	70. 984	559. 346	......	......	
		71. 860	560. 222	. 876	700	
26	Shoal near Big Elk Creek.	74. 756	563. 118	......	......	
		75. 000	563. 362	. 244	275	
27.7	Mill Shoal	75. 828	564. 190	......	......	There is a grist-mill at this shoal run by an undershot wheel.
		78. 481	566. 843	2. 653	800	
	Mill Dam	79. 532	567. 894	......	......	The head of the shoal is dammed in order to give a sufficient water-supply and velocity in the race-way.
33.5	Lick Shoal, foot	81. 647	570. 009	......	......	
	Lick Shoal, head	86. 214	574. 576	4. 567	1, 300	
33.9	Marrow-bone Shoal...	86. 214	574. 576	......	......	
		87. 163	575. 525	0. 949	350	
34.6	Buck Creek Shoal.....	87. 163	575. 525	......	......	
		88. 663	577. 025	1. 500	500	
35.0	Warfield, Ky., low-water mark.	88. 663	577. 025	......	......	The population of this place, according to census, is 522. The salt-works manufacture salt enough to supply home consumption. These works have facilities to supply a large market should there be any demand. There is also a saw-mill and a grist-mill in good condition. An opening for coal has been made, which shows very fine coal.

P 7.

SURVEYS FOR EXTENSION OF THE CHESAPEAKE AND OHIO CANAL FROM CUMBERLAND TO PITTSBURGH—PRELIMINARY REPORT.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, January 23, 1875.

GENERAL: It having been found impracticable to complete, before the middle or the close of February, the report on the surveys made during the summer and autumn of 1874 for the extension of the Chesapeake and Ohio Canal, from Cumberland to Pittsburgh, I directed Col.

onel Sedgwick, the assistant engineer in charge of this survey, to send in at once a preliminary report, in order that Congress might receive information of the progress of the survey in time to take such action as might be deemed advisable in regard to the completion of this work.

From this report it appears that the line of the canal has been definitely located from Cumberland to a point two miles north of Ohio Pyle Falls. The sum allotted for the survey was insufficient to carry the work beyond this point. The total distance surveyed was seventy-eight miles, leaving seventeen miles yet to be surveyed in order to reach Connellsville, at which place it is expected that the canal will terminate, and that the remainder of the line, to the mouth of the Youghiogheny, may be completed by slack-water navigation in the river itself. The lower portion of the river (from West Newton to its mouth, a distance of nineteen miles) was surveyed under my direction, in 1873, by Lieut. F. A. Mahan, engineers. The distance between Connellsville and West Newton is twenty-four miles. There are, therefore, yet to be surveyed seventeen miles of canal and twenty-four miles of river. The reason why the survey did not reach Connellsville was on account of the extraordinarily difficult nature of the line, made yet more complicated by the occupancy of the narrow valleys by a railroad, built on the exact site originally chosen for the canal. The railroad fully doubles the difficulties in traversing the valley of Wills Creek.

The conclusion thus far reached is, that it is simply impossible to construct a canal of the usual type between Cumberland and the summit-level. This conclusion substantially holds for the route surveyed in 1873 by way of the North Branch of the Potomac and Savage River. Whichever route be chosen for the canal, this portion of it must of necessity be wholly or partly built after the style so long in successful use on the Morris and Essex Canal; that is, the ascent of the heavier grades by inclined planes. On this canal, at places where the lift is so great that it would otherwise require many locks and short pools, the boats are taken on carriages whose platforms conform to the slope of the plane. These carriages are drawn up by water-power, obtained from a turbine placed at the lowest attainable position and supplied with water from the upper level. A dam is thrown across the end of the upper level in order to retain the water, and this dam must be ascended and descended by the carriages, thus adding to the total distance to be lifted. Where a single plane is used, the whole weight of boat and carriage must be lifted, and the total friction of all the machinery must be overcome. With a double plane there is a partial counterbalance. In both cases the work to be performed is variable, and necessitates a careful management of the power in order to avoid too slow a motion in one case or too rapid a one in the other. The change of grade at the summit is particularly disadvantageous, as at the commencement of the maneuver both carriages are rising out of the water.

To avoid these difficulties Colonel Sedgwick proposes to use double planes, and to transport the boats in caissons, in which they will be water-borne. By this means the ascending and descending carriages will always exactly counterbalance, and the power will only be used for overcoming the hurtful resistances. In addition, he proposes to avoid the crossing of the dam at the end of the upper level by using gates, and by so arranging the caissons that, by means of these gates and of gates in the caissons themselves, direct communication may be made between the water in the upper level and the water in the caisson. The boat will thus pass at once from the caisson into the upper level, and similarly into the lower one.

In this preliminary report of progress it is not necessary to discuss these planes in detail. It will suffice to state that whether caissons should be used or not will depend upon similar calculations as to the work to be done with or without their use. The system which promises the least expenditure of water, consistent with effectiveness in other particulars, will be the one that will be recommended for adoption.

I regret to state that the results of the present survey will yet leave the estimates incomplete. The work that will remain to be done will be as follows: Seventeen miles of canal survey, Ohio Pyle to Connellsville; twenty-four miles of river survey, Connellsville to West Newton; survey and estimate of summit-reservoir; survey and estimate of auxiliary reservoir near summit; gauging rivers and creeks; revision of special sections of former line.

The surveys and estimates for the main summit-reservoir, the auxiliary-reservoirs, the gauging of the streams, and the general question of water-supply, are matters that require special attention, as the practicability of this route depends entirely upon the possibility of securing an adequate supply of water. I think that this can be done; but we have had no time as yet to make it a special study. It is quite evident that there will be no great surplus of water, and that the reservoirs will require to be of considerable magnitude.

The last item has been included, because it is very desirable that some portions of the line, especially that part in the valley of Wills Creek, should receive a careful revision. This valley presents extraordinary difficulties, and a thorough revision of some of its worst sections is exceedingly desirable. From a careful personal examination, I think that I can safely say that no canal has ever been built on a line presenting such formidable obstacles to be overcome as this Wills Creek division.

To accomplish the work marked out above would require two parties under one chief. The first party should complete the survey from Ohio Pyle to West Newton. The second party should study the question of water-supply, and should revise the line in difficult places. * *

The chief of the whole survey should be employed continuously until the survey is finished, or ceases from lack of an appropriation. I therefore estimate his services for one year.

It will take the first party about three months and a half to finish the field-work between Ohio Pile and West Newton, and there will be about three months' office-work for the engineers of the party. The second party will require about four months for field-work and three months for office-work. A draughtsman will also be required at the office of the chief of the survey in compiling the general maps of the survey, and in making drawings of the locks, aqueducts, inclined planes, &c. This will probably occupy him for a year. The total estimate will be as follows:

Chief of survey, 12 months, at $300	$3,000
Draughtsman, 12 months, at $150	1,800
First party, 3½ months in field, at $1,465	5,128
First party, 3 months in office, at $585	$1,755
Second party, four months in field, at $1,110	4,440
Second party, 3 months in office, at $435	1,305
Office-rent	500
	18,528
Contingencies, 8 per cent	1,472
Total sum required	20,000

Whether this canal route be adopted or not, I think that it is due to the important interests which desire it that a full report should be made as to its practicability. I therefore strongly recommend the grant of the sum herein requested, in order that our two years' investigation may be brought to a fitting close.

The detailed discussion of the line will be reserved for the final report on the surveys of 1874.

Respectfully submitted.

WM. E. MERRILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

ANNUAL REPORT

UPON THE

IMPROVEMENT OF THE OHIO, MONONGAHELA, GREAT KANAWHA, AND WABASH RIVERS; WATER-GAUGES ON THE MISSISSIPPI AND ITS TRIBUTARIES,

IN CHARGE OF

W. E. MERRILL,

MAJOR OF ENGINEERS, BVT. COLONEL, U. S. A.;

BEING

APPENDIX N

OF THE

ANNUAL REPORT OF THE CHIEF OF ENGINEERS FOR 1874.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1874.

[EXTRACT FROM THE ANNUAL REPORT OF THE CHIEF OF ENGINEERS TO THE SECRETARY OF WAR.]

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., October 20, 1874.

* * * * * * *

IMPROVEMENT OF THE OHIO RIVER.—IMPROVEMENT OF MONONGAHELA, GREAT KANAWHA, AND WABASH RIVERS.—WATER-GAUGES ON THE MISSISSIPPI AND ITS TRIBUTARIES.

Officer in charge, Maj. W. E. Merrill, Corps of Engineers, having under his immediate orders Lieut. F. A. Mahan, Corps of Engineers.

1. *Improvement of the Ohio River.*—Of the contracts outstanding at the commencement of the fiscal year, those for dams at Chartier's Creek, Wheeling, Marietta, Buffington Island, and Cumberland Island have been completed. The work on the dike at Evansville has progressed satisfactorily. It has not, however, been considered advisable to push the work, because it was thought best to give the river time to accommodate itself gradually to its new channel. The bar at the Evansville Landing has already been reduced several feet in height, and the engineer in charge is very confident that the current thrown upon it by the dike will eventually complete its removal. No trouble is now experienced here, except at very low stages of the river. The removal of the Bacon Rock, at the mouth of the river, was begun near the close of the year, and it will probably soon cease to be an obstruction.

During the year contracts have been made for the construction of a dam to close Duck Chute, at the head of Brunot's Island; for the repair of the old dikes at French and Henderson Islands; for the building of a new dredge and dump-scows, and for the construction of an iron hull for a new snag-boat. The Duck Chute dam was finished last season, but the water has since cut new outlets around its ends, which may require closing at some future time. The dike at French Island has been completed since the close of the fiscal year, and that at Henderson is progressing rapidly, and will be completed during the season. These are both substantial improvements. The dredge and scows were finished last season. The snag-boat is still in process of construction.

The dredge Ohio, after completing work on the bar at Captina, where she was on the first of July, proceeded to Buffington Island and remained there until the end of the season. Work was resumed the present season by the Ohio, together with the new dredge Oswego, on the bar at the foot of Brunot's Island, and at the close of the fiscal year the removal of this bar had been nearly completed. The amount excavated during the year is as follows: By the Ohio, 260 cubic yards at Captina Island, and 40,336 cubic yards at Buffington; by both dredges, 38,038 cubic yards at Brunot's Island.

A great many obstructions have been removed from the channel this year by special contracts. Among these are the wreck of a dry-dock, near Cincinnati; the wreck of the steamer McCullough, near Madison, Ind.; the wrecks of several coal-barges at Vevay, Ind.; a large number of rocks near Mustapha Island and at the Parkersburgh Railroad bridge, and about half of the wreck of the steamer Missouri, near Evansville, Ind. Many snags and smaller wrecks have also been removed.

The officer in charge gives a description of the difficulty of improving the Lower Ohio on account of the great masses of sand and gravel that are constantly moving down in this part of the river, and concludes his report by presenting a plan for radically improving the Upper Ohio. between Pittsburgh and Wheeling. He recommends the construction of movable dams, similar to those in use in France on the Seine, the Yonne, the Marne, the Meuse, and the Moselle. Of the many systems in use in France he recommends the adoption of the "Chanoine," so-called after its inventor. By this system dams can be built which will raise the water-surface to a height of from 12 to 14 feet above the bed of the river, but which can be thrown down in a few minutes when there is a sufficient natural supply, leaving the river entirely open to navigation. Connected with these movable dams are locks, for use when the dams are up. For the convenience of coal-fleets, he recommends locks 630 feet between gates and 75 feet wide. Extra gates in the middle will divide the lock into two shorter ones, for the benefit of packet-steamboats.

The approximate estimate of the cost of this improvement from Pittsburgh to Wheeling is $7,474,623. It is believed, however, that this estimate can be reduced when the detailed surveys, now in progress, are finished.

Estimate for the next fiscal year by the officer in charge.

For constructing 13 locks, between Pittsburgh and Wheeling, $200,000 each	$2,300,000
For engineering and contingencies of lock-construction, 5 per cent	130,000
To complete iron snag-boat	35,000
Running expenses of two dredges	27,000
Running expenses of snag-boat	18,000
Building dikes on Lower Ohio	170,000
Office expenses	20,000
Total	3,000,000

Estimate for the next fiscal year as revised in this Office.

For constructing one dam and lock and one weir and gate near Pittsburgh	$632,000
For wing-dams, dredging, and removing snags and bowlders	270,000
Total	902,000
Balance in Treasury of United States July 1, 1873	230,000 00
Amount in hands of officer and subject to his check, (including $4,620.30 percentage due on contracts not yet completed)	26,675 96
Amount appropriated by act approved June 23, 1874	150,000 00
Amount expended during the fiscal year ending June 30, 1874	207,286 47
Amount available July 1, 1874, ($199,389.49—$4,525.65)	194,863 84
Amount required for the fiscal year ending June 30, 1876	902,000 00

(See Appendixes N 1 and N 2.)

Hydraulic gates and movable dams.—The board of engineer officers constituted to examine and report upon the plan of Mr. F. R. Brunot for movable hydraulic gates for chutes and locks, its applicability to the improvement of the Ohio and other rivers, and to estimate the cost of its construction, to which duty was subsequently added the general consideration of the whole subject of movable hydraulic gates and of all other proposed plans for this object, submitted their final report, which was transmitted to Congress at its last session, and printed in H. R. Ex. Doc. No. 127.

(See Appendix N 3.)

2. *Improvement of Monongahela River.*—The progress thus far made in the construction of the lock at Hoard's Rocks has been slow, and it is not probable that it will be finished this season, although the first and most difficult courses of the walls will be laid.

Two additional locks and dams will be required to connect this improvement with the slack-water already established on the lower river. Of these the officer in charge recommends that the United States should build the upper one, leaving the other to be built by the Monongahela Navigation Company.

The estimate submitted by the officer in charge for the next fiscal year is $132,000 to complete the improvement in progress at Hoard's Rocks, and in addition to construct a lock at or near Cheat River Ripple.

Balance in Treasury of the United States July 1, 1873	$90,000 00
Deduct amount expended in last fiscal year....................................	409 14
Amount appropriated by act approved June 23, 1874	25,000 00
Amount expended during the fiscal year ending June 30, 1874.............	6,120 13
Amount available July 1, 1874, ($108,470.73 — $403.84)...	108,066 89
Amount required for the fiscal year ending June 30, 1876, (as revised in this Office)..	22,000 00

(See Appendix N 4.)

3. *Improvement of Great Kanawha River.*—The officer in charge reports the condition of this improvement up to August 15, at which date the work was transferred to the charge of Maj. W. P. Craighill, Corps of Engineers.

The contracts outstanding at the commencement of the fiscal year for works of improvement at Elk Shoal and at Two-mile Shoal have been satisfactorily fulfilled. The contractor has been released from his obligation to construct a dike at Cabin Creek Shoals; a careful examination of the river at this point having satisfied the engineer in charge that the proposed work would not answer the purpose for which it was intended.

A crane-boat, fitted out with a large grapple and towed by a small steamboat, worked fourteen days last fall and thirty-one days the present season in removing rocks and snags from the channel of this river. This work has given great satisfaction to the navigation interests.

As the navigation of this river will doubtless ultimately be improved by the use of locks and dams, the officer now in charge of its improvement, Major Craighill, suggests that to commence this system an appropriation of not less than $150,000 should be made for the year ending June 30, 1876.

Should Congress, however, decide to defer entering upon that method of improvement, but to continue the unsatisfactory and insufficient process now pursued of operating upon the shoals, the sum of $15,000 is all that will be required.

Balance in Treasury of United States July 1, 1873..............................	$25,000 00
Deduct amount expended in last fiscal year	352 98
Amount appropriated by act approved June 23, 1874.........................	25,000 00
Amount expended during the fiscal year ending June 30, 1874.............	14,322 21
Amount available July 1, 1874, ($35,324.81—$800.54.)........................	34,524 27
Amount required for the fiscal year ending June 30, 1876..................	150,000 00

(See Appendix N 5.)

4. *Improvement of Wabash River.*—The contracts for snagging and dredging in the lower river, and for rock-excavation and wing-dam at Coffee Island Chute, have been completed.

A contract was entered into in August, 1873, for 23,000 cubic yards of rock-excavation at the Grand Chain, thirty-eight miles from the mouth of the river. This work has been prosecuted satisfactorily thus far, and will probably be completed by December 1, 1874, as contemplated by the terms of the contract.

The officer in charge deems it indispensable that the lock and dam at Grand Rapids should be reconstructed. A survey of the river in the vicinity of these rapids, completed since the close of the fiscal year, proves this point to be the best site for the rebuilding of the lock and dam, since the lowness of the banks of both the Wabash and White Rivers renders it inexpedient to place them at White River Shoals, a site which it was hoped would be found eligible, inasmuch as a dam here would materially improve the navigation of the White River, and at the same time obviate the necessity of further improvement of those shoals.

The estimate of the amount required for the next fiscal year includes the clearing out of the chute east of the Little Chain.

Negotiations have been commenced with the Wabash Navigation Company looking to the purchase of all their rights over the free navigation of this river, as contemplated by the proviso attached to the last appropriation for continuing this improvement. After the extinguishment of the rights of this company it is hoped that sufficient funds will be left of this latter appropriation to construct a dam to close the cut-off at New Harmony.

Balance in Treasury of United States July 1, 1873	$65,000 00
Amount in hands of officer and subject to his check (including $2,772.83 percentage due on contracts not yet completed) July 1, 1873	5,542 40
Amount appropriated by act approved June 23, 1874	25,000 00
Amount expended during the fiscal year ending June 30, 1874	47,558 35
Amount available July 1, 1874, ($47,984.05 — $2,647.80)	45,336 25
Amount required for the fiscal year ending June 30, 1876	130,000 00

(See Appendix N 6.)

5. *Water-gauges on the Mississippi and its tributaries.*—One new gauge, that on the Cumberland River at Nashville, has been added to the system during the year, and the gauges at St. Louis and Cairo have been thoroughly and permanently reconstructed. The lower Louisville gauge has also been recut upon the walls of the lower canal-lock, the original graduation of this gauge having been erroneous.

It is deemed advisable to reconstruct all these gauges in a permanent manner, as rapidly as the available funds will permit, whenever the banks are sufficiently stable to warrant such a construction.

The records of the flood of 1874, collected this year, will be of great importance in the discussion of the problem of reclaiming the alluvial lands of the Mississippi. These have been placed in the hands of the commission appointed for that purpose.

Balance in Treasury of United States July 1, 1873	$5,000 00
Amount in hands of officer and subject to his check	813 37
Amount allotted from appropriation of June 23, 1874, for examinations and surveys	5.000 00
Amount expended during the fiscal year ending June 30, 1874	5,787 16
Amount available July 1, 1874	5,026 21

(See Appendix N 7.)

EXAMINATIONS AND SURVEYS FOR IMPROVEMENT.

The exploration of routes for the *extension of the Chesapeake and Ohio Canal* to the Ohio River by the north and south branches of the Potomac, directed by the act of March 3, 1873, was completed under the direction of Major Merrill, and the report thereon transmitted to Congress at its last session, and printed in H. R. Ex. Docs. Nos. 208 and 265 (See Appendix N 8.)

The *survey of the Youghiougheny River*, Pennsylvania, also provided for by the same act, has likewise been completed under the direction of Major Merrill. For the report thereon see Appendix N 9.

* * * * * * *

REPORT.

APPENDIX N.

ANNUAL REPORT OF MAJOR WM. E. MERRILL, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1874.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, September 1, 1874.

GENERAL: I have the honor herewith to transmit annual reports on the works under my charge for the fiscal year ending June 30, 1874.

Lieut. F. A. Mahan, Corps of Engineers, has been my military assistant during the year, except from December 8, 1873, to May 14, 1874, inclusive, during which time he was on temporary duty at Savannah, Ga., under the orders of Lieut. Col. Q. A. Gillmore, Corps of Engineers.

Very respectfully, your obedient servant,

WM. E. MERRILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

N 1.

IMPROVEMENT OF THE OHIO RIVER.

At the beginning of the fiscal year the following contracts were outstanding.

Number.	Miles from Pittsburg.	Work.	Contractors.
1	3	Repair of Chartier's Creek dam	Charles Cable.
2	90	Repair of Wheeling dam	C. M. Cole.
3	168	Repair of dam at head of Marietta Island	C. M. Cole.
4	214	Repair of dam and dike at Buffington Island	C. M. Cole.
5	783	Construction of dike at Evansville, Ind	J. S. Routh.
6	907	Repair of dam at Cumberland Island	Miller & Bedard.
7	967	Removal of the Bacon Rock	Miller & Bedard.

Chartier's Creek dam, three miles below Pittsburgh.—This dam was completed in August, 1873, and the contract was closed. The total amount of stone expended under this contract was 32,480 cubic yards. It has answered its purpose satisfactorily. It closes the left channel at Brunot's Island, throwing all the water in low and ordinary stages into the Glass-house Channel.

Wheeling dam, ninety miles below Pittsburgh.—The repairs of this dam were finished in August, 1873. They required in all 3,508 cubic yards of stone and 425 cords of brush. It closes the right or Ohio channel at Wheeling Island, thus increasing the low-water volume in the other channel.

Marietta Island dam, one hundred and sixty-eight miles below Pittsburgh.—This dam is at the head of Marietta Island, and closes the right or Virginia Channel. The work of repairing this dam was completed in September, 1873. It required 8,304 cubic yards of stone and 177 cords of brush. It backed up the water so much more than I had expected that I thought it expedient to strengthen it by a brush and pile dam below, and thus divide the fall, which at certain stages was as great as 5½ feet, and was more than I considered it prudent to attempt to sustain by a dam of loose stone. I therefore had an auxiliary dam built, whose upper line was placed 50 feet below the lower edge of the main dam, with its top surface 3 feet lower than that of the latter. This auxiliary dam was made as cheaply as possible of two rows of piles, 6 feet apart, with 30 feet between the rows, and the inclosed space was filled with brush, weighted down with stone. Some stone and brush were likewise used in protecting the banks. This auxiliary work required an expenditure of 316 piles, 5,941 cords of brush, and 4,553 cubic yards of stone. There has been no trouble in using the right channel since the left one was closed, except occasionally at the foot and opposite the mouth of the Muskingum. This river sometimes throws out a mass of sand and sediment that occasionally troubles coal-fleets. This difficulty has lately been removed by dredging.

Buffington dam and dike, two hundred and fourteen miles below Pittsburgh.—These works were finished in September, 1873. The total amount of stone expended on both was 26,078 cubic yards.

Evansville dike, seven hundred and eighty-three miles below Pittsburgh.—At the close of operations in 1873, this dike had been finished for a length from shore of 1,025 feet. I directed Mr. Charles B. Bateman, assistant engineer, the inspector of this and Henderson dikes, to examine the dike occasionally during the winter, and especially to report any effect that might be produced on the sand-bar at the upper end of the city, for the removal of which the dike was designed. He reported on the 31st of December that the deposit on the wharf from the recent rise is much less in quantity than usual; also that from the line of the highest water said deposit is clayey mud down to about the 20 foot line, from which line down it consists of sand and gravel in patches evidently washed from the bar. * * * The current during the rise and since the river has commenced falling, has been decidedly on the Indiana shore, the drift giving considerable trouble to steamers and wharf-boats at the landing.

On the 30th of March he wrote:

> I observe that during the several rises of the past few months there has been no deposit on the wharf below 23.50 feet on the gauge at that stage, and below a strong current sweeps the Indiana shore from the water-works down—the effect, it is presumed, of the dike.

On the 23d of May he writes:

> Soundings were taken over the bar from Mulberry street to Main, when the river was at 12 feet by the gauge, and were as follows:

	Feet.
On highest part of the bar, opposite Mulberry street	7.50
Opposite Cherry street	8.60
Opposite Chestnut street	9.00
Opposite Walnut street	10.50
Opposite Locust street	12.00

> Below Locust street, no bottom at 12 feet, showing that at least four feet has been taken off the bar during the past winter. The current on this side is stronger than before, and there is evidently a channel cut along the scour made along the bar during the winter of 1872–'3.

On the 1st of June he writes:

> On the bar in front of the city I made soundings, and found one little ridge opposite the water-works, near the shore, which is now four feet above low water. No other part of the bar will be more than 2.50 above low water when dry. Opposite the foot of Main street, where the bar used to be, there will be six feet at low water.

The dike itself is firm and solid, and a large sand-bar has formed below it. The dike will be extended 300 feet farther during the present season. I have purposely kept this work back, in order to give the river time to accommodate itself to the new course marked out for it. A rapid construction of the dike would have caused so great a scour at its outer end as to materially increase its cost. At present the pocket behind the bar has been filled by material washed into it from the bar, and more or less of the same is scattered along the city front, making landings difficult in low water. This temporary annoyance could not have been prevented. The bar is still so high that in extreme low water it cuts off the river current. When the bar is entirely washed away these troublesome deposits will depart with it. I consider this dike a marked success in its effectiveness, its strength, and its cheapness. All future dikes in the Lower Ohio will be built in a similar manner.

Cumberland dam, nine hundred and seven miles below Pittsburgh.—The repairs on this dam were completed in December, 1873, under contract with Messrs. Miller and Bedard.

The total amount of stone used was 20,187 cubic yards. Owing to the long duration of high-water last autumn, at a time when the river is usually at its lowest, it was impossible to finish this work as completely as was desired, as during the last six weeks the dam was continuously under water. I made as close a personal inspection as was practicable, and, feeling satisfied that nothing more could be done to advantage, closed the contract. During high-water of the winter and spring the dam was subjected to a severe test. All of the new work except a small section about 100 feet in length stood very well, but to my surprise the river leveled down a large part of the old work which had been standing for over thirty years, and was assumed to be safe and strong. During the present season I called for proposals for bringing this part of the dam up to grade, and let the new contract to Mr. Bedard, the active member of the old firm of contractors. He bid at his old price, which was considerably lower than the price offered by any other bidder. Six thousand yards more will be placed in the dam, and there is reason to believe that this amount will make it safe and substantial. There will always be a strong pressure against it, as the high-water current is over the dam, and therefore deposits will annually form in the chute, which must be removed by the current as the water falls and is forced by the dam into the chute. Thus far there has been no serious trouble with the new channel at the head of Cumberland Island, but that at the foot of the island is changeable, and will probably require some construction to fix it.

Bacon Rock, nine hundred and sixty-seven miles below Pittsburgh.—This rock was formerly on the Missouri shore of the Mississippi River, but owing to the gradual change of the channel of the Mississippi it is now in the Ohio River, though a slight wash of the sand-bar between the two rivers would throw it into the Mississippi. It is a very serious obstruction in low-water. The contractors, Miller and Bedard, did nothing for the removal of this rock, and their contract was declared forfeited. One of their sureties, Mr. M. A. Bryson, then claimed the right to complete the contract, and his right was acknowledged. During low-water last season he made some preparations, and waited for the water to fall before commencing work. Contrary to custom the river rose, and remained up, consequently nothing was done. During the present season, at my suggestion, he employed Capt. R. W. Dugan, of the Cincinnati Wrecking Company, to do the work for him. At the close of the year Captain Dugan had exploded, by surface-blasting, a large number of charges of dynamite on the rock, and had entirely broken up its shell. He found the interior of the rock (which is a pudding-stone) to be mainly loose gravel. This will be removed by a dredge, and before this report reaches Congress the Bacon Rock will probably be a thing of the past.

NEW CONTRACTS.

The following new contracts were made during the fiscal year just past:

Number.	Miles from Pittsburgh.	Work.	Contractor.
1	2	Dam across Duck Chute	C. M. Cole.
2	760	Repair of old dike at French Island	C. M. Cole.
3	797	Repair of old dike at Henderson Island	J. S. Routh.
4	......	Construction of dredges and dump-scows	S. B. Alger.
5	......	Construction of iron snag-boat hull	Swift's Iron and Steel Works.

Duck Chute, two miles below Pittsburgh.—Duck Chute is a small channel across the bar at the head of Brunot's Island, and near the high land of the island. It is usually dry at extreme low-water. It was necessary to close it, as the current through this opening drew coal-fleets out of the channel leading into Glasshouse. The dam was finished in September, 1873, having consumed 1,995 cubic yards of stone. It entirely closed the channel across which it was built, but the pressure of water in that direction was so great as to cut out the gravel at each end of the dam, and as much water now escapes as before its construction. If the radical improvement of the Ohio be inaugurated it will probably be unnecessary to extend this dam; if the contrary be the case, its extension will be very necessary.

French Island Dike, seven hundred and sixty miles below Pittsburgh.—Since the close of the fiscal year this dike has been completed, as also some slight repairs to the dike, extending down from near the foot of the island. The work has given great satisfaction to the Louisville and Henderson packets, as French Island was the shoalest place on their route. Three and a half feet is as much as I think can be depended on in extreme low-water, though the contractor thinks he can guarantee 4 feet. A greater depth might be secured by a greater contraction, but that is inadmissible on account of the coal-interest. The following quantities of material were used: 2,815 cubic yards of stone, 5,409 cords of brush, and 705 piles. The total length of the new dike is 2,000 feet.

Henderson Island Dike, seven hundred and ninety-seven miles below Pittsburgh.—At the close of 1873 this dike had been extended into the river 1,000 feet. Its effect was excellent from the first, a good channel having been maintained throughout the low-water season.' Unfortunately this good effect was not lasting. During low-water of June, 1874, the slight obstruction to the flow of the river occasioned by the dike was enough to cause the channel behind the island to cut out, and in extreme low-water steamboats had to take that route. This channel was very narrow and intricate, and was full of snags and water-soaked logs, making an exceedingly bad place for steamboats, and one quite impracticable by night. I made a careful personal examination, finding 3½ feet at the head of the chute, and less than 3 feet in the old channel, the river being a foot or two above dead low. No steamboat could get through the chute without hitting at least one log. I concluded that the proper remedy was to close the chute entirely by a pile and brush dam, thus forcing all the water through the channel marked out for it. This work was approved by you, and is now under way. At present the dike is finished for a distance from shore of 1,050 feet, and piles have been drived for an additional distance of 250 feet. It will be extended to a total length of 1,500 feet.

I have always been apprehensive of the possible need of a dam behind Henderson Island, but I was unwilling to spend the money needed to build it until its necessity was demonstrated, and the fact that in former years no such dam had been built strengthened me in my conclusion that it might prove unnecessary now.

New dredge and dump-scows.—The new dredge Oswego and two dump-scows have been built by Mr. S. B. Alger, under his contract of July 11, 1873. The hull of the dredge is 75 feet long and 30 feet wide, with 5 feet 9 inches depth of hold. She draws 2 feet 8 inches of water when loaded with 600 bushels of coal. Her cylinders are 10 inches in diameter, with 14-inch stroke, and she is provided with one of King's marine-boilers, having eighty 3-inch return-flues. A steam hoisting-apparatus is provided for the forward spuds, and a steam-capstan for maneuvering. The clutch used is Alger's patent friction-clutch. It is somewhat liable to breakage, but when in order works rapidly and well. By making it of steel, and keeping a spare clutch on hand, there need be no serious loss in case of accident. The scows are side-dumpers, with bins capable of holding 71 cubic yards. They are 65 feet in length and 20 feet in width, and have 4 feet depth of hold. They are built without crown or sheer, and draw when empty 15 inches. They can carry 50 cubic yards of gravel on 3 feet 6 inches of water. The contract-price of dredge and scows was $18,500. An additional sum of $2,000 was spent on outfit, making the total cost of dredge and two scows about $20,500.

Iron hull snag-boat.—The contract for building the hull of the iron snag-boat for the Ohio was taken by the Swift Iron and Steel Works, at $84,350. During the winter but little work was done, on account of the financial depression and of strikes at the works. At present everything is progressing rapidly, and the hull is about one-third finished. Its construction will supply a long-felt need.

Traveling sands in the Ohio below the falls.—The greatest obstacle to the successful improvement of the Lower Ohio comes from the enormous masses of sand and gravel that travel down stream during every rise.

Behind the dikes at French and Henderson islands, and at Evansville, sand-bars have formed as high as the dikes, and in places where before, or during their construction, there was deep water. At the Cumberland Island end of the Cumberland dam, where last season there was about 10 feet of water, there was this season 10 feet of sand, showing a deposit of 20 feet in one season. The sand behind the dikes mentioned above is mixed with gravel, and as it is impossible for gravel to be carried in suspension, it must have rolled along the bottom The up-stream sides of the dikes are vertical, or nearly so, and I can see but two ways for the gravel to get over the dike. It might have reached the upper line of the dike and there got attached to ice which carried it over when the river rose, and then dropped it below the dike. This action has undoubtedly taken place at Louisville, at the revetted slope on the up-stream side of the dam at the head of the falls. The other supposition is that in high water the bottom of the river was raised by deposit to the level of the dike, and that before the dike became visible the deposit on its up-stream side was washed away. This I think the more probable explanation, especially in view of the fact that during the ice-period of last winter all of the dikes were submerged many feet. There is abundant additional experience to show that during high-water the bottom of the river is habitually raised by deposit, and that the low-water channel, is subsequently cut out of it as the river falls. This condition makes the radical improvement of this part of the Ohio a matter of serious difficulty. A further discussion is reserved for the report on the radical improvement of the Ohio, which has been ordered for the Senate Committee on Transportation.

DREDGING.

The work of dredging has been vigorously prosecuted during the year, under the direction of Mr. E. J. Carpenter, assistant engineer. On the 1st of July, 1873, the "Ohio" was at Captina. The cut at this place was finished by the removal of 260 more yards, and the dredge was moved to Buffington Island. The "Ohio" continued work on the bar at this place, which is one of the worst on the river, until compelled by cold weather to lie up. She dredged 8,983 cubic yards in July, 10,285 in August, 11,907 in September, 6,662 in October, and 2,760 in November, making a total of 40,596 cubic yards. During the last month the new dredge Oswego joined her, but neither dredge could do much, on account of high-water. The work of the "Oswego" amounted to but little, as all of her machinery was new and required to be worked into smooth running. The little dredging done by her has been credited to the "Ohio."

The dredges were laid up at Marietta in the mouth of the Muskingum until the 1st of May. They were then sent to Pittsburgh to remove the bar at the foot of Brunot's Island, which gave great trouble to coal-fleets. Sixteen thousand two hundred cubic yards were removed in May and 21,839 in June, making a total of 38,038 cubic yards removed from the bar. No further difficulty is anticipated at this place. The dredges are still at work, but their subsequent operations belong to the present fiscal year.

REMOVING WRECKS AND OBSTRUCTIONS.

The winter of 1872–'73 was unusually severe, and when the ice broke up it destroyed many river-craft, and left numberless wrecks in the channel which could not be discovered until low-water of summer.

Capt. R. W. Dugan, with the boat of the same name, blew up and removed the wreck of a section of dry-dock that had lodged in the channel at Rising Sun, and the wreck of the steamboat McCullough near Madison. Captain Hobson, with a crane-boat, removed several logs and minor wrecks in the immediate vicinity of Cincinnati. There were several wrecked coal-barges in the channel at Vevay. I tried to get a dredge from the Louisville Canal for this work, but, being unsuccessful, I made application to the Kanawha board, and was permitted to hire a dredge from them. This dredge removed the barges at Vevay, but a sudden rise in the river compelled her to stop work and return to the Kanawha. In August one large log was removed by a crane-boat from the channel at Cullum's Ripple, and another lying opposite Covington.

The navigation of the Ohio being greatly hindered in low-water at Mustapha Island, Guyandotte Shallows, Poag's, Jenalt's, and other places, I had a large grapple built for the express purpose of removing bowlders. This grapple is 11 feet in height, has a grasp of a little more than 5 feet, has four fingers on each side, weighs 2,700 pounds, and cost $1,174. The following obstructions were removed by the use of this grapple: the rocks at the foot of Mustapha Island, where the channel is now in good condition; several rocks in the channel-span of the Parkersburg bridge, carelessly thrown there by the bridge-builders, and two snags between Parkersburg and Marietta. This grapple has been used to great advantage on the Great Kanawha. For details, reference is made to the annual report of operations on that river.

A snag was removed by hired labor from the foot of Ranty's Shallows, and the Government snag-boat S. H. Long was borrowed from Major Suter, engineers, and was employed four days in cleaning out the chute at the head of Cumberland Island.

During October, four troublesome snags were removed from Quick's Run Bar by a hired crane-boat. A section of the dry-dock was blown up at the foot of Ludlow street, Cincinnati, and the greater portion of the wreck of a stone-boat was removed from Rising Sun bar. A sudden rise in the river prevented its entire removal.

A wrecking party provided with diver, armor, battery, and torpedces was equipped and put to work at the wreck of the Missouri, a very large and strongly-built steamboat, lying just above the Evansville dike. About half of this boat was removed by the close of the season.

In May, one log was removed from the mouth of the Muskingum, and three others from the head of Blennerhassett's Island.

OFFICE-WORK.

The office-work during the year has comprised the preparation of a continuous map of the river, on the scale of 2 inches to the mile, of detailed drawings for the snag-boat, of hydrographs of the Ohio River gauge-records, of drawings to accompany the report of the Board of Engineers on movable dams and hydraulic gates, of drawings and tracings of special surveys, and of miscellaneous work of various kinds.

ESTIMATE FOR 1875-'76.

The first question to be settled is the general method of improvement. After long study, I have come to the conclusion that the best method of improving the Ohio, at least in the upper part of its course, is to follow the plans that have been so successful on the Seine, Younne, Marne, Meuse, and other French rivers. The details of all the methods in use in France are given in full in the report of the Board of Engineers on movable dams and hydraulic gates, which is printed as Ex. Doc. No. 127, H. of R., 43d Cong., 1st sess.* The system that meets with most favor in France is that known from its inventor as the Chanoine. A drawing of the more important features of this system accompanies this report. The Brunot gate will probably be a useful auxiliary to this or any other system that may be adopted, and I had expected to have an opportunity of testing its practicability on a working scale before the meeting of Congress. As it has been decided that money appropriated for the Ohio cannot be expended on a dam in the Monongahela, this trial has necessarily been abandoned. While I regret this, I do not consider that its lack will have any influence on the method of movable dam that may be selected for use.

There is nothing to prevent the subsequent trial and adoption of the Brunot gate on one of the movable dams should it seem desirable. It is merely a useful adjunct at best, and not an indispensable necessity.

A Chanoine wicket, when in position, is a solid frame of timber about 3½ feet wide and 13 feet high, sloping down stream and supported behind by a heavy iron prop. The horse is hinged to the wicket and to the floor. The prop turns on the upper axle of the horse, as does also the wicket. The latter is not fastened to the floor except by the horse, and can swing around the upper axle of the latter when not held down by the pressure of water. A series of such frames or panels makes the dam. The intervals between the frames are about 2 inches, and if it is necessary to make the dam tight these intervals can be covered. Usually the waste through them will be less than the discharge of the river, and therefore the level of the pool will not fall below the tops of the wickets.

The dam is thrown down by means of a long iron bar laid on top of the masonry-base, extending from one shore to the other, and armed with projections or shoulders. By moving this rod a few feet, which is done from the abutment by proper gearing, the feet of the props are tripped successively, and the wickets fall into a shallow recess where they are below the reach of passing boats. The river is then in its natural condition, offering no obstacle to boats nor to the passage of floods. In the navigable pass nothing projects higher than 2 feet below low-water line. On the weir the height of masonry is usually about 20 inches above low water.

The wickets are raised in succession by the use of a boat which works across the stream. It has a sheave in its bow, and a geared drum near the stern. The first wicket is raised by the boat being so placed that its bow projects beyond the abutment half the width of a wicket. The hoisting rope has a boat-hook fastened to its outer end. The man at the bow hooks the boat-hook over a handle at the lower end of the wicket, and the other man then winds up the rope. The wicket is thus raised, pulling up with it the horse and the prop. When the horse is at its proper elevation the prop drops into position. The wicket is still nearly horizontal, and if it is let go it will retain an inclined position with the water rushing under it. A slight push on its lower end brings it against the sill, and the water pressure holds it in place. After one wicket is raised the boat is pushed out the width of a wicket, supporting itself partly against the abutment and partly against the wicket first raised. This operation is continued until all the wickets are in place.

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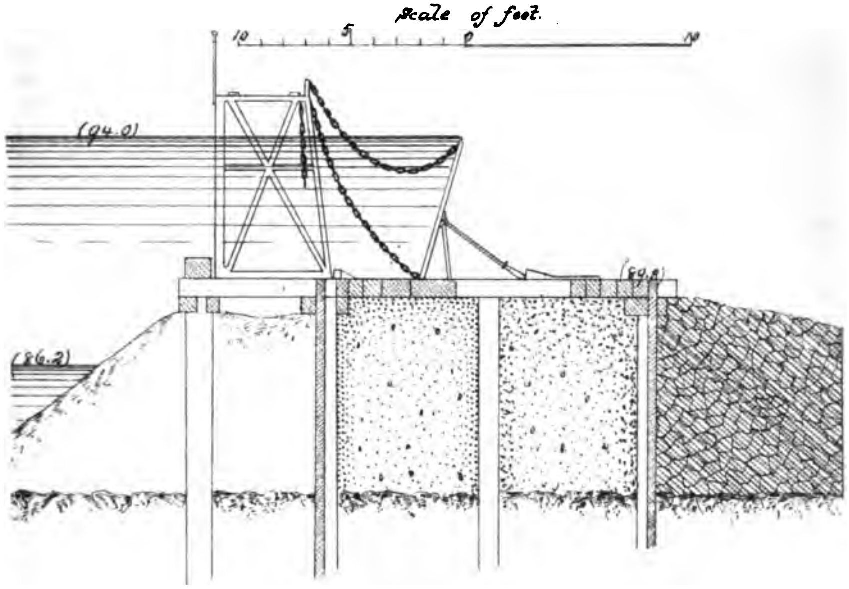
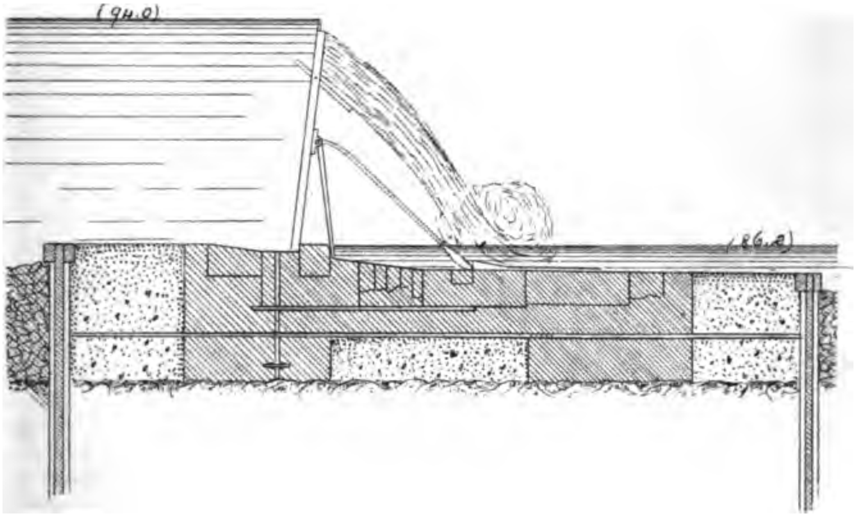
* See Appendix N 3.

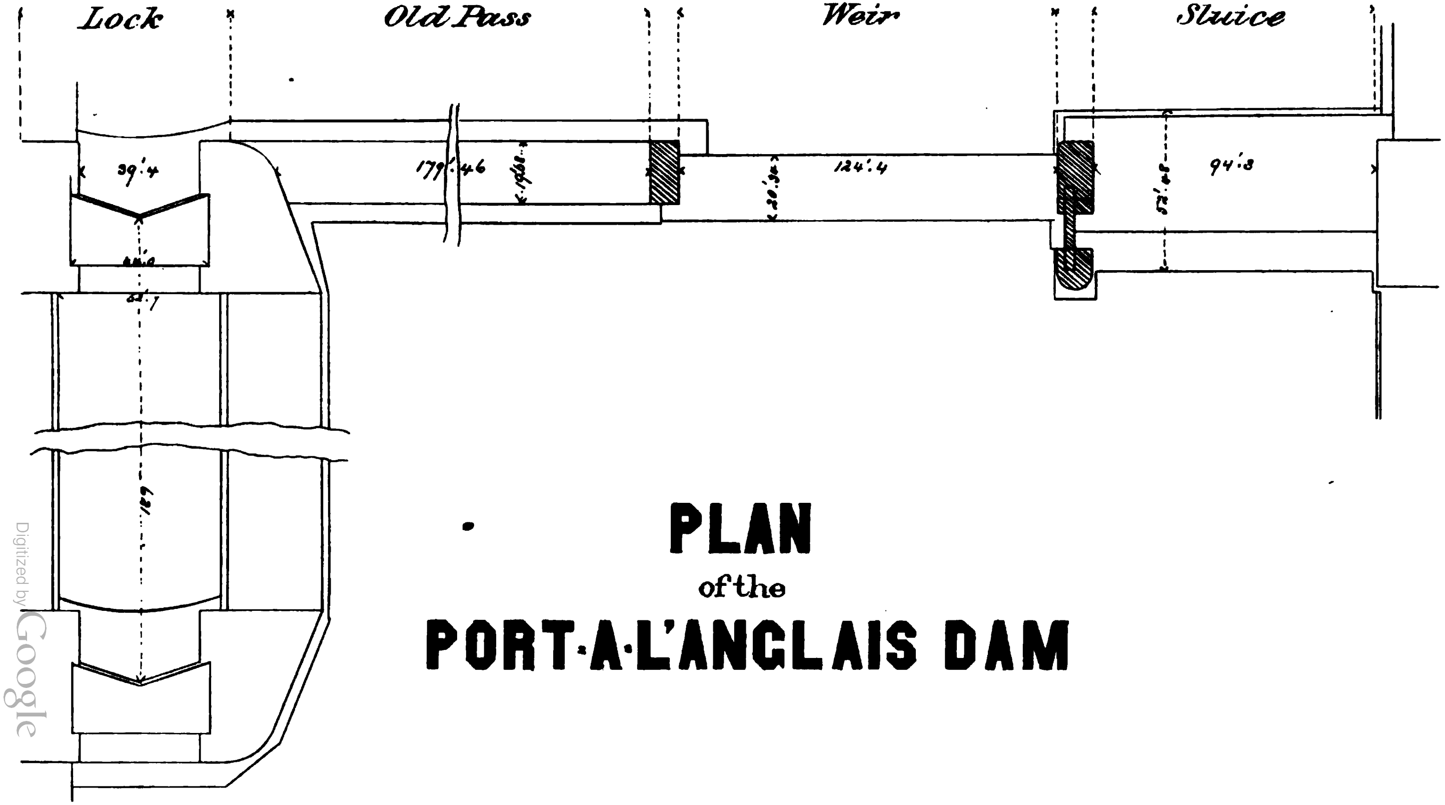
PORT-A-L'ANGLAIS DAM



Section through weir

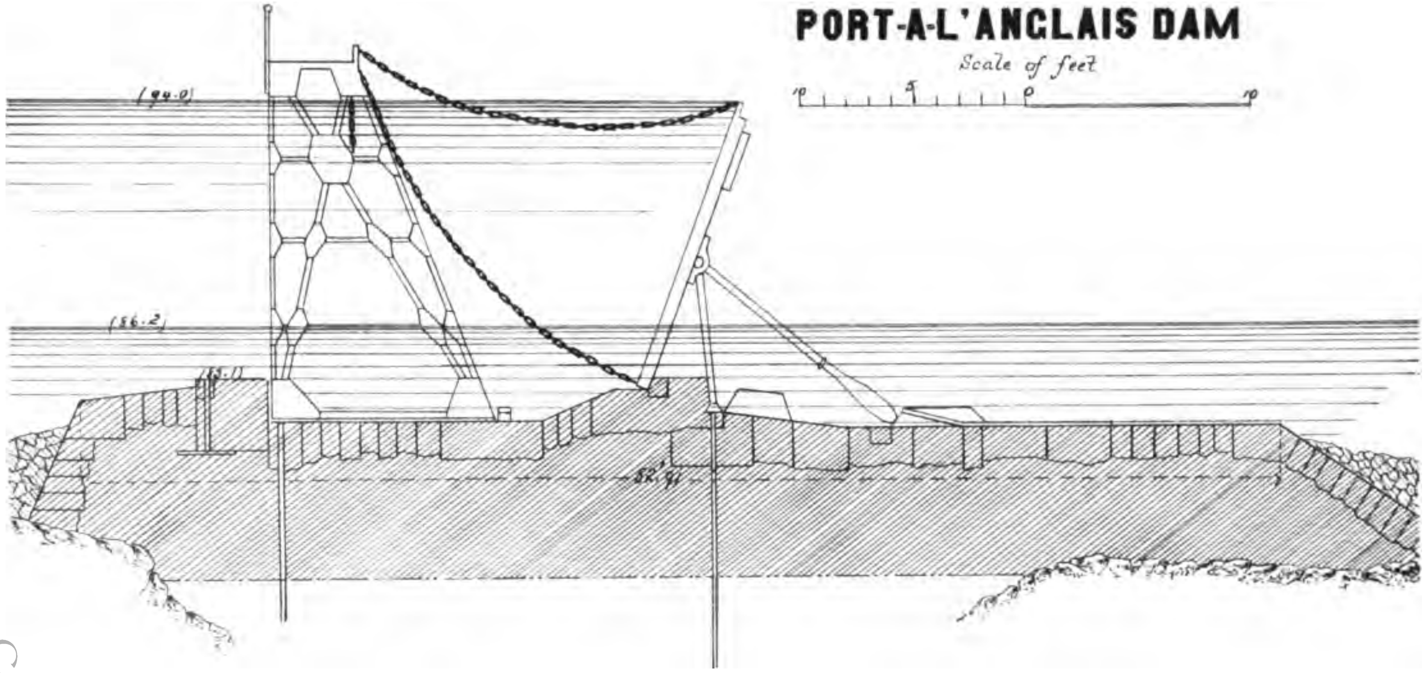


Section through old navigable pass



PLAN
of the
PORT-A-L'ANGLAIS DAM

PORT-A-L'ANCLAIS DAM



Section through new navigable pass or sluice

At many dams there is a temporary bridge above the wickets from which they are raised. This is probably the better method, but in a wide river it would probably cause some delay in getting the wickets up, unless a considerable force of laborers were kept on hand to expedite operations. Two or three men are all that are employed in France to manage a lock and movable dam.

Assuming then a method of improvement by movable dams on the Chanoine plan, we require the following constructions:

1. A movable dam of Chanoine wickets divided into navigable pass and weir.
2. A lock large enough to pass an ordinary coal-fleet through in one lockage.

The dams should have a vertical height of 12 feet, that being as far as present experience goes, about the greatest practicable height of a movable dam. The lift from one pool to the next will be 6 feet, and there will be a minimum depth of 6 feet below each dam, thus securing a 6-foot navigation at all times.

I have already chosen the approximate position for a sufficient number of dams to make a 6-foot navigation at all seasons between Pittsburgh and Wheeling. I do not think it advisable to make an estimate at present for extending this work below Wheeling. The sites and length of dams are as follows:

No.	Place.	Miles from Pittsburgh.	Length.
			Feet.
1	Just below Horsetail Ripple	5¾	900 +600
2	Between Duff's and Merriman	8½	1,000
3	Just below the trap	12½	1,500
4	Just below Deadman's Island	15½	1,300
5	At Crow Island	21	1,350 +400
6	Below Montgomery's Island	32½	1,600
7	One mile below Georgetown Island	38¾	1,200
8	Just below Baker's Island	49½	1,850
9	One and a half miles below Black's Island	55	1,700
10	One mile above Steubenville Bridge	65	1,000
11	At Cox's Bar	72	1,250
12	At head of Pike Island	83	1,700
13	At Wheeling	90	1,000 +800
	Sum		19,150
	Average length		1,473

Where two lengths are given in the above list, the dam rests on an island, and there are two channels to be closed.

The width of navigable pass is an undetermined quantity. Coal-fleets are generally four barges or 100 feet in width, but at times they have a width of five barges, (120 feet,) or even of six barges, (144 feet.) As they will have the smooth wall of the lock to guide them into the pass, I think it will be quite safe to limit its width to 250 feet. The rest would be weir and Brunot chute, should the latter prove a success, or weir only if the contrary.

Experience in France shows that the locks should be large enough to pass a coal-fleet, either ascending or descending, at one lockage. An average fleet has ten barges, (130 by 24 feet,) one fuel-flat, (100 by 22 feet,) and one steamboat, (230 by 48 feet.) The barges could pass two abreast if the locks were 50 feet wide, three abreast if they were 75 feet, four abreast if they were 100 feet wide. The first size is, however, too small for packet-steamboats which require from 60 to 80 feet, and the last-named size is too wide to be closed by the ordinary lock-gate. The width of the lock must therefore be 75 feet.

To hold such a coal-fleet as I have described above, the available length of lock must be 620 feet, and this should be increased to 630 to give play for the gates, and to avoid a tight fit.

The lock should therefore be built with a length between miter-sills of 630 feet, a width of 75 feet, and an ordinary lift of 6 feet, but with strength enough to sustain a pressure of 10 feet, which would happen should the lower pool be emptied in low-water.

This length may seem excessive, but the advantage of passing a fleet at one lockage is very great, and the increase of cost is not in proportion to the length of lock. The most expensive parts of a lock are the gates and the masonry around them, and these cost the same in all locks of the same width and lift, regardless of their length. The difference between a short and a long lock of the same width and lift is only the cost of the extra length of chamber wall, and this is the cheapest masonry about the lock. The fleets on the Seine are somewhat smaller than those on the Ohio, though their larger barges have almost exactly the same dimensions as Ohio coal-barges. (See Ex. Doc. No. 127, H. of R., 43d Cong., 1st sess., page 51.) To pass one of these fleets at a single lockage, the lock-chambers on the Upper Seine have a width of 40 feet, and an available length of from 591 to 615 feet.

In order to avoid delay and waste of water when a single steamboat wishes to pass through, the locks should have extra gates at the middle, so that the whole length of lock need not be used unless occasion called for it. This will add somewhat to the expense, but I believe that the advantages of diminishing the amount of water needed lor lockage during very low stages, and of expediting the passage of packet-boats, will be worth obtaining.

The cost of such a lock as I have described, would be, in round numbers, $200,000. The cost of 13 such locks will therefore be about $2,600,000.

These figures will be somewhat modified when a detailed estimate can be prepared. A special party is now at work definitely locating the proposed dams that I have approximately located above, and making borings to determine the character of foundation at each site. This information will be embodied in the report ordered for the Senate Committee on Transportation, and will somewhat modify the approximate estimate herewith presented.

The cost of the movable dams will be:

$344 per running foot for the pass.
$227 per running foot for the weir.

These estimates for the dams have been carefully prepared under my direction by Lieutenant Mahan, by using the itemized bills of materials prepared from actual construction in France, and are believed to be quite accurate. No account has been taken of the Brunot chute, which, if successful, will replace a part of the weir. It would, however, increase the cost of a dam.

A movable dam of the average length of 1,473 feet will then cost as follows:

250 feet of pass, at $344 per foot	$86,000
1,273 feet of weir, at $227 per foot	288,971
Total for one movable dam	374,971
Thirteen movable dams without locks will therefore cost	4,874,623
The cost of a single lock with movable dam will be	574,971
And the whole cost of this improvement from Pittsburgh to Wheeling	7,474,623

In beginning this work we should first build the locks, as during the construction of the dams they will answer as waste-weirs, and will also keep open a passage for navigation. I think that at as early a date as possible this work should be simultaneously begun at all points between Pittsburgh and Wheeling, because it will take all of two seasons to build these locks, and their construction must precede that of the dams. There is no doubt whatever of the absolute necessity of using locks in any rational plan for improving the Upper Ohio so as to secure a 6-foot navigation. Whatever changes may be made in the details of the dams, the locks must be the same.

For this part of the improvement of the Ohio, I therefore now ask for	$2,600,000
Engineering and contingencies of lock-construction, 5 per cent	130,000

Besides this special sum, I request the following:

To complete snag-boat	$35,000
To keep dredges at work 9 months, at $3,000	27,000
For six months' service of snag-boat, at $3,000	18,000
For improving Lower Ohio by dikes	170,000
Office expenses	20,000
Total	3,000,000

I have not thought it necessary to attempt detailed estimates on the dikes for the Ohio below the Falls, as this work is so dependent on unforeseen contingencies that such estimates are of little value. The bars that are in most need of improvement are Portland, Flint Island, Puppy Creek, Scuffletown, Three-Mile Island, Shawneetown, Treadwater, foot of Cumberland Island, and the Grand Chain.

Financial statement.

Balance in Treasury of United States July 1, 1873	$230,000 00
Amount in hands of officer and subject to his check, (including $4,620.30 percentage due on contracts not yet completed)	26,675 96
Amount appropriated by act approved June 23, 1874	150,000 00
Amount expended during the fiscal year ending June 30, 1874	207,286 47
Amount available July 1, 1874, ($199,389.49—$4,525.65)	194,863 84
Amount required for the fiscal year ending June 30, 1876	3,000,000 00

N 2.

IMPROVEMENT OF THE OHIO RIVER BELOW THE FALLS.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, November 30, 1873.

GENERAL: In reply to your letters of September 1 and October 1, I would submit the following in regard to the improvement of the Ohio below the falls so as to secure a depth of 5 feet at low water. I regret that I have been absent on duty so much lately, and have been so busy on board-reports, that I have been unable to take up the subject earlier; but as I gave my views at length in my testimony before the Senate Committee on Transportation, for whose information (as I was informed) these questions were asked, I trust that the delay has not been injurious.

The first question in your letter of September 1, reads as follows:

> Please inform this Office whether you are prepared to submit a project for improving the Lower Ohio River, from Louisville to Cairo, so as to afford a depth of not less than 5 feet at the lowest stage of water known. If not, please state what additional information you require to enable you to prepare such a plan.

In reply I would state that the only plan which I am at present prepared to recommend is the one now in use throughout the whole river, and that is the concentration of the currents by dikes or wing-dams, and the closing of all but one channel where there are two or more. Whether this method will secure five feet during dead low water I cannot now tell, but I am rather of opinion that it will not. It is possible that we might secure four feet, but experience alone will answer this question. I should state that no work was done on the Lower Ohio by Mr. Roberts, and that I have only commenced the work this season, and consequently have too little experience in this matter to give a positive reply The dikes at French and Henderson Islands are both under way, but it is not likely that either will be finished this season. The latter was commenced first, and its effect was so quickly felt that there was no trouble at this bar during this summer's low water. But the mere fact of boats being able to cross this bar does not show the maximum that could have been brought over, as during the low-water season there was only 20 inches on French Island bar, (the work at that time had not begun there,) and from two to three feet on some others, and therefore all boats were running very light. Last year I commenced work at Cumberland Dam and at Evansville dike, but the object in view at each of these places was the changing of old channels, and not their deepening, and, besides, both of these works are unfinished.

One great difficulty in improving this part of the river is that the coal-fleets that start from Louisville for southern markets are much larger than those that come from Pittsburgh to Louisville, and this fact, together with the lack of definiteness in land-marks in the river below the Falls, makes it dangerous to reduce the channel-width below 600 feet, and of course the same depth cannot be expected in a wide as in a narrow channel.

There is another point on which reasoning is of little avail, and experience alone is to be trusted. That is, whether or not the sands that are swept through narrow artificial channels will not form below, and the practical result be simply a change of position of the bar, without increase of depth. If the work formerly done on the Ohio had been kept in good condition, and carefully observed and reported upon, we should now be able to settle this matter; but our records are unfortunately defective, and the old works have themselves been so degraded that they now exercise no perceptible influence on the bars. I have in this office all the records about the Lower Ohio that I could secure in the Department or elsewhere, and I herewith present, in chronological order, a summary of all the opinions on the effect of dams and dikes in the Lower Ohio which I could gather from the records.

The earliest report on file in this Office, which records the results of work on the Lower Ohio, is by Colonel Long, in reference to the dike at Henderson Island. His report is in the shape of marginal notes on the drawings which he forwarded to the Department. On his "Sketch No. V," a copy of which I send herewith, there is the following note. The remarks in brackets and the italicizing are mine:

> From the diagram now before us it will be perceived that the bed of the river has undergone a material change since the commencement of our operations. * * * * * * A portion of the sand accumulated above the dam during the freshet before mentioned [winter of 1824–'25] contributed to form the circular bar at the lower extremity of the dam, across the outward margin of which the depth of water is *only three feet* as represented in the sketch. A large quantity of sand previously situated in the bed of the river above the dam, was now distributed over the space between the dam and the dry-bar below, occasioning the shoal presented in that part of the river. The elevation of the bar above the dam, with the exception of the channel contiguous thereto, remained about the same as it was at the commencement of the work this year, although its position approximated considerably nearer to the island.

The general depth of water in this part of the river, at the time alluded to, was *from 2¼ to 3 feet*, but owing to subsidence of 18 inches, which took place during the progress of the work, its depth was now only about *one-half that above mentioned.* The position and depths of the channel, occasioned by the dam, are indicated by the drawing, in which are inscribed a series of soundings, corresponding to the depth of water actually found in the channel at this very low stage of the river. At the lower extremity of the channel the depth is *only* 3 *feet* for a distance of 12 or 15 yards; but the sand is here exceedingly loose and yielding, the current setting strongly across it, and daily rendering the channel deeper and broader. It is not expected that the channel occasioned by the dam will continue to occupy the position it now has longer than the present season, for the following reasons: The next freshet will probably bring down a large body of sand from above, and deposit it immediately above and below the dam in such a manner as to form a bar rising to the top of the dam throughout its whole length; such being the event, the most elevated part of the bar will be that portion of it situated contiguous to the dam, so that when the river subsides, the water, instead of being drawn off through a channel adjacent to the dam, as is now the case, will pass over a less elevated part of the bar at a considerable distance above it. Should the result prove as here stated, there can be little doubt either of the efficiency or permanency of the work, for it will then be protected from the undermining influence of the current, and secured from the shocks of floating ice and drift of every description to which it would otherwise be exposed.

I would particularly call attention to the following points on the sketch: The limited depth of water across the bar, the narrowness of the channel indicated, and the shoal formed below the dike.

Captain R. Delafield, Engineers, in his report, dated January 16, 1833, (Doc. No. 66,) states as follows about the work on the Lower Ohio:

> The last class of works [deepening the water on the bars] has now been so far tested as to render no longer doubtful the success of removing the bars from their present position, and to this period entirely accomplishing the object in view of giving a permanent and unchangeable 3½ and 4 foot channel-way.
>
> With a judicious location of the dams, I am more fully confirmed in the belief that permanency may be secured to all such works, and that removing the bar from one point shall not form another immediately below. This is the only doubt as to the entire success of the works of this class.
>
> The results thus far have been satisfactory. Last year two of the most difficult and shoalest bars were dammed, as shown by figures 1 and 2 accompanying this report.
>
> On the Scuffletown Bar (Fig. 2) there was formerly but 18 to 20 inches water at the low stage of the river. Since the dams have been constructed there is four feet, and no injurious formation below it, all the sands having apparently been deposited under the lee and eddy made by the dam, and the channel confined within permanent banks.
>
> A reference to Fig. 2, No. 8, of my report of 1831, will exhibit the position of the shoals at that time, and the present sketch (Fig. 2) will give an idea of the change effected by constructing the dams.
>
> Fig. 1 is a sketch of another system of dams constructed last year, that have been productive of satisfactory results at the Sister Islands. In this case, as the previous ones, the sands washed from the bars have been deposited under the lee of the dams. Fig. 4, No. 12, of the report of 1831, exhibits what was then supposed to be the position of the shoals at that time, and the sketch accompanying this report (Fig. 1) the present position of the shoals. If these two figures are correct, a very great change has been made in the whole bed of the river, proving the facility with which the channel may be deflected in any direction, and the necessity of having surveys for each and every one of these bars, to judge properly of the effect produced.

I append to this report copies of Captain Delafield's maps of the bars at French Island, Scuffletown, and the Sisters, the work being then under way at the first-named place, but finished at the other two. He shows a depth at French Island of 2½ feet, at Scuffletown of 4 feet, and at The Sisters of 3½ feet.

There are on file in this office sketches of the dams at French Island, Scuffletown, Three Mile, and The Sisters, made by Lieut. A. H. Bowman, Engineers, in 1835, in connection with some maps of work on the Cumberland. These sketches have neither scale nor soundings, and the report that probably accompanied them is not on file in this office.

Capt. R. E. Lee, Engineers, in his inspection report to the Chief Engineer, dated November 20, 1839, a manuscript copy of which is on file in this office, writes as follows:

> The dam at the Three Sisters has entirely removed the shoal that formerly existed at this point, and has become strengthened by an accumulation of sand and gravel which renders it permanent.
>
> A breach has been made through the dam at Three Mile Island, through which was the deepest channel at the time of my inspection. It was but partially constructed in 1833 and 1834, and intended to concentrate the water at the foot of the island, from which extended a gravelly shoal. The yielding of the dam still allows its expansion, which would be prevented by its repair and completion.
>
> The effect of the two piers at Scuffletown has been entirely successful in removing the bar at that place, which was formerly one of the greatest obstructions on the river. One of the piers requires to be raised; a beneficial effect has also been produced by the piers at French Island, though in their present condition they but imperfectly answer the purpose for which they were constructed. A settlement has taken place in both piers, which requires them to be raised.
>
> The success of the plan of improvement where it has been fairly tried, viz: The Three Sisters, Scuffletown, and French Island, shows its importance if fully carried out. These were once among the worst points on the river, and they now offer no impediment to the navigation.

In a document on file in this office, issued by the Wabash Navigation Company, dated Vincennes, April 24, 1847, and signed by John Ross, secretary, there is a comparison between the low-water navigations of the Wabash and the Ohio, from which I make the following extracts:

> In the report of Lieutenant-Colonel Long, communicated to Congress by the President of the United States in 1843, on the improvement of the western rivers, "about 2 feet water" is assumed as "the utmost that should be aimed at in providing for a general system of low-water navigation." (Doc. No. 2199.) (Not on file in this office.) And in the same report, page 188, Colonel Long states in relation to the Ohio River above and below the Falls, as follows:
>
> "I think the practicability of securing a greater depth (than two feet) in extreme low-water very doubtful if not quite hopeless." * * * * * * * Mr. Burr, (the engineer who made the first report to the company on the lock and dam at Grand Rapids,) in his report January, 1839, p. 8, states: "For three months in the year there is not commonly in the Ohio River, above and below its confluence with the Wabash, for boats over the bars, more than from two to two and one-half feet water, and this season less than two feet."

I have also maps of the bars at French Island, Scuffletown, and Three Mile Island, made by A. Campbell and F. Saunders. These maps are not dated, but, from references to a particular stage of water, I infer that they were made in October, 1844. There is no accompanying report on file, and no information on the map to show what was the stage of the river when the surveys were made. The maps show 3 feet at French Island, 4.2 feet at Scuffletown, and 3½ feet at Three Mile. At the latter place the channel is very intricate, and passes through gaps in the dike. The channel which the dike was to have made is filled with sand, so that the depth through it is but one foot.

This sums up all the information that I have been able to obtain on the practicability of radically improving the Lower Ohio by dikes. Better results could probably be obtained now, as we have additional experience in dike-building, but the possibility of securing by this means 5 feet during extreme low-water, while maintaining a sufficiently wide channel for coal-fleets, is very doubtful if not impossible. If the banks of the Ohio and of all its larger tributaries could be thoroughly protected from abrasion so as to cut off the supply of sand, we might hope for better results; but the expense of such a work is too great for consideration. As land becomes more valuable, greater efforts will be made to protect river-banks, but it will be long before any appreciable effect can be produced on the bottom of the river.

I think that the statements given above will show that the information needed to prepare a plan for improving the lower Ohio by controlling the currents can only be acquired by experience. I have already sufficient surveys for all practical work likely to be attempted for several years.

In your last paragraph you ask my opinion about improving the lower Ohio by dredging. I have no hesitation in saying that dredging in the ordinary way would be useless. A dredge could not dig out more than two bars in a season, and the work would probably have to be repeated annually at great cost. A steamboat with scraper would do excellent service, as one day at a bar would suffice, and she could help a dozen or twenty in a season; but the true method of working at bars in light sand is to direct the river-currents on them. There is, of course, a danger that the bar will re-form below, but an extension of the dike will probably drive it away. This system might ultimately result in having continuous dikes throughout the river, but it has the advantage of being the cheapest system that can be adopted, and no more dike-work need be done than the case demands at the moment.

When work was begun at Henderson Island bar the only shoal place was abreast of the island. When I resumed work there this season there was another bar at the foot of the island, which evidently did not exist in 1825. I thought it probable that I would have to build a dike there also, but thus far the single dike at the old place seems to prove sufficient. Colonel Long's dike did not touch either shore. In this it differs from all other dikes ever built on the Ohio. I do not consider the plan judicious, and therefore the dike that I am building starts from the main Indiana shore.

The question of reservoirs may be suggested by some, I can only say that, for reasons given in my annual reports, I consider reservoirs impracticable for the Upper Ohio, and still more so for the Lower. Unless additional reservoirs were built on all the lower tributaries, there would not be a sufficiency of water. The upper reservoirs are expected to give six feet at Pittsburgh. Experience shows that a six-foot rise at Pittsburgh is entirely lost by the time it reaches the falls, unless it is sustained by rises in the lower tributaries. We have no data for determining exactly how much water would be needed to give five feet in the Lower Ohio, nor do I consider it worth while to go to the expense of getting them.

I have recommended for the Upper Ohio locks and dams, with a chute opened and shut by a hydraulic gate. If the dike system does not work in the lower Ohio, we can try locks and dams. The only hesitation I have in recommending it comes from the immense mass of sand that is always in motion below the Falls. Experience in India shows that it is perfectly feasible to build dams on a foundation of pure sand. In the Roorkee Treatise on Civil Engineering, page 494, occurs the following sentence: "Several anicuts (dams) have recently been built with perfect success, and at a moderate expense, across rivers, the beds of which consist entirely of pure sand to a depth beyond the foundation of these works." On page 499, Colonel Baird Smith, Bengal Engineers, in summing up his conclusions about damming sandy rivers, considers the following, (among other points,) as established by Indian experience: "That in rivers with beds of pure sand, and having slopes of 3½ feet per mile, dams may be constructed and maintained at moderate expense; that the elevation of the beds of the rivers above the dams to the full height of the crowns of these works is an inevitable consequence of their construction, and that no arrangement of under-sluices has, as yet, been effective to prevent this result."

We may, therefore, feel assured of the practicability of building such dams, and need now only discuss the question of the moving sands. The only way that I can now see to remedy the difficulty is to give notice that for a given week navigation will be suspended. I would then commence at the lowest pool, and drain it off through the chute. After this was emptied I would let the chute remain open, and drain the next pool through the two chutes, the third through three, and so on. I believe that by this method I would scour a navigable channel through all the pools to the depth of the floors of the chutes.

But the lock and dam system will naturally be tried first in the upper end of the river. Long before it is necessary to start it on the lower river we will have acquired abundant experience on both systems of improvement.

Respectfully submitted.

WM. E. MERRILL,
Major of Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers.

N 3.

RADICAL IMPROVEMENT OF THE OHIO RIVER BY HYDRAULIC GATES AND MOVABLE DAMS.

Report of the Board of Engineers.

JANUARY 31, 1874.

GENERAL: The board of engineers appointed by par. 1, General Orders 44, Headquarters Corps of Engineers, April 16, 1872, "to examine and report upon the plan of Mr. F. R. Brunot for movable hydraulic gates for chutes and locks, its applicability to the improvement of the Ohio and other rivers, and an estimate of the cost of construction," to which duty was subsequently added, by letter dated May 1, 1872, the general consideration of the whole subject of movable hydraulic gates and of all other proposed plans for this object, would respectfully submit the following report. A preliminary report, dated January 14, 1873, was sent to the Department, in which the board, without specifying any particular plan, stated that there was no doubt of the practicability of attaining the object desired, and recommended an appropriation of $40,000 for the purpose of testing the matter on the Monongahela. As this report did not reach Congress, no appropriation was made. Since then the board has been actively engaged in studying the history of similar works in this country and abroad, and in testing by large models all the various plans that appeared likely to answer the purpose. They are now prepared to submit a plan which they feel confident will fully meet the necessities of the case.

The special importance of the investigation in question comes from its intimate connection with the slack-water plan for radically improving the navigation of the Ohio. This method of improvement has received the sanction of the great majority of the engineers who have investigated the subject, and it has also been approved by the Ohio River commissioners, a body composed of five delegates, appointed by the governor, from each of the seven States bordering on the Ohio River or its tributaries.

The commercial interests of the Ohio Valley demand that the river shall be so improved as to secure a minimum navigation of 6 feet. There are but two apparent ways of securing such a depth: by retaining in huge reservoirs the surplus of high stages, and letting it out in low ones, and by constructing dams and locks in the bed of the river. There are so many serious objections to the former system, that it has received but little support, either popular or scientific. But a discussion of the merits of the two systems is foreign to this report. The nature of the investigation which we have been required to make presupposes an improvement by slack-water.

The lack of water in the river is, as might be supposed, most marked near its head. In the first twenty miles below Pittsburgh the average fall per mile is 17 inches; in the second twenty miles, 7.7; in the third, 7.8; in the fourth, 8.7; and in the fifth, 10.8. The average per mile of the first one hundred miles is 10.4 inches, and the average per mile from Pittsburgh to Louisville is 6.3 inches. From the foot of the falls to Cairo the average per mile is 3 inches. The method of improvement by contracting the channel, though accomplishing some good, will manifestly not secure the required 6 feet, as can readily be seen by examining the river at White's Ripple and the Trap, eleven miles below Pittsburgh. Here the whole body of water passes through a space whose width at low water is 230 feet, and yet at that stage the depth for navigation is frequently but 12 inches. Whatever improvement may be made, here it is manifestly impossible to secure the depth needed for a successful navigation, if we limit ourselves to guiding the natural supply.

In the Upper Ohio by far the most important navigation is the transport of coal. Pittsburgh annually ships over fifty million bushels to points below, and all the large cities from Cincinnati to New Orleans receive their principal supplies from this source and in this way. Under existing arrangements all this coal comes out on floods of 7 feet or more, a single steamboat bringing down from eight to twenty barges. The representatives of this interest, although not content with the river as it is, would prefer no change, unless it were of such a character that they would have no more delay or trouble in getting their fleets down the river than they have now. Coal-fleets are so large and ponderous, that they require a wide river for maneuvering; and, besides, the barges must be bound together in every direction in the firmest possible manner by cables and screw-clamps. It is very tedious and difficult to make up a coal-fleet, and somewhat hazardous; and it is almost indispensable that, when the boats are once firmly connected, they should remain so until the whole fleet is landed at its destination. For this reason the passage of a lock after the fleet has started is most objectionable, and would cause insupportable delay and danger. The coal-interest of Pittsburgh is therefore a unit in opposing the erection of any dam in the Ohio River, unless some modification can be introduced into the ordinary slack-water system that will permit the passage of fleets without requiring them to be broken up and re-formed below the dams. The slack-water system is undoubtedly very costly, and if opposed by a large class of river-men it would be almost impossible to secure the funds necessary to get it into operation. It may therefore be considered as settled, that the adoption of the system of locks and dams on the Ohio River is dependent upon the practicability of making an opening in each dam of sufficient with' to pass a coal-fleet without any delay, of constructing a movable hydaulic gate to open or close this opening at will, and of building a chute or inclined plane of such length and shape that there will not be an excessive velocity in it nor any objectionable wave at its entrance or its exit.

The average width of a coal-fleet is 125 feet. The least width of chute that can now, in advance of experience, be assumed as necessary is 200 feet. The first question therefore is, can a gate be constructed that can be made to close or open this passage at will.

EXTRACTS FROM HAGEN AND BECKER.

The following extracts from Hagen and Becker, two of the most prominent writers on hydraulics, will show what has thus far been done in this country and in Europe in cases similar to the one with which we have to deal. We will first state that, in order to preserve clearness in the descriptions which we are about to give, all gates turning around an axis fastened to an edge will be called *shutters;* those whose axes are at or near the middle will be called *wickets.*

After discussing generally the uses of movable dams and their importance, Hagen proceeds to enumerate the different plans that have been suggested, prefacing it with the remark that no one seems yet to furnish a full solution of the problem. He then says:

> A complete solution of the problem seems to require that the pressure of the water, whether standing or flowing, should furnish the power by which the dam is erected or removed. Or, again, the construction must be such that, notwithstanding the requisite solidity of the structure, it can be managed with a slight power, for which only a few men and a short time are required.
>
> On the improvement, or rather converting into a canal, of the Lehigh River, (Pennsylvania,) which empties into the Delaware at Easton, Josiah White built a movable dam in 1818, which is maneuvered solely by the pressure of the water, and which he therefore called the hydrostatic dam. (Chevalier, Histoire et description des voies de communication dans les Etats-Unis, Paris, 1843, Vol. 11, page 464.) It is hardly proper to call them dams, as they really only form the lower gates of locks. Nevertheless the same arrangement is without doubt useful in the construction of an independent dam. Figs. 1, 2, and 3 show a portion of the plan and two longitudinal sections, showing the arrangement of the dam when the gates are opened and closed, taken from the model, as the Wiener Bauzeitung informs us.
>
> The dam is created by a gate which turns on a horizontal axis, and which can be laid flat on the floor. This abuts when it is raised against a second similar gate, whose axis is on the down-stream side. The latter, according to Chevalier's statement, is twice as long as the former, which, however, does not agree with the drawing before us. Both gates close as tightly and firmly as possible against each other, the floor, and both side walls. By this means the pressure of the water under the gates can be increased or diminished by placing it in connection with either the water above or below. The gates rise as soon as the inclosed water receives the pressure from the water above, and lower as soon as the space beneath them is placed in connection with the water below. The two wickets in the side culverts serve for the purpose of creating or cutting off the connections referred to. In order, however, that the gates may not rise too high, projecting strips are applied to both of the side walls, and, in addition, there is a third projecting strip on the lower side of the first gate, which is shown in the drawing. The gates must never rise so high as to become perpendicular to each other, as in this case they could not be dropped.
>
> The lift which is created by this arrangement is in one case 29 feet high, but at the other seven locks it is less. A dam of this construction is said to have been built in the Enz, at Besigheim, in the kingdom of Würtemberg, with complete success.

Hagen then mentions a plan of movable dams which has been proposed. It consists of placing boxes or caissons alongside of each other, which are loaded in such a manner that at low stages of the water they will firmly settle to the bottom, but when the water reaches a certain point they will rise and float off. He says of this:

> The difficulties of executing this plan, especially in swift water, appear, after careful consideration, so great that, as far as is known to me, no attempt has yet been made to apply this idea to dams in rivers. At dry-docks, arrangements of this character are in use, but in these cases there is no current, either in placing or removing them, since the water on both sides is at the same height.

He then gives a description of a dam on the principle of the one suggested by General Moorhead. He says:

> Other dams are so arranged as to fall when the pressure of the water increases. The wicket-gate with horizontal axis is an example of this class. The gate or wicket, when closed, rests at its lower end against a shoulder in the top of the dam. As long as the water above is below the horizontal axis of the wicket, its pressure increases its stability. But when the water rises above the axis, a counter-pressure is created. Both of these pressures only become equal (provided the down-stream water does not touch the wicket) when the up-stream water stands twice as high above the axis as this is above the top of the dam. If the water rises higher than this, the pressure on the upper part of the wicket becomes greatest, and it falls.
>
> Figures 4, 5, 6, and 7 show a dam with this arrangement in the Riom, in the department of Puy de Dome. (Annales des Ponts et Chaussées, 1842, I, page 231.)
>
> There are three openings in this dam, each 12 feet 9 inches in length; the wickets, consisting of a double layer of planks, are 2 feet 3 inches high. They extend into the abutments, where they turn in recesses whose edges support the wickets and diminish the leakage, besides preventing the wicket from turning down too far. The other peculiarities of this arrangement are shown by the drawings; but it must be borne in mind that when the water falls the wickets do not raise themselves, but must be lifted up from the abutments by means of hooks.
>
> Similar turning gates or wickets may be held in an upright position by means of hanging weights. At high stages these counterpoises are submerged, and their loss of weight causes the wickets to fall down; when the water falls the weight of the counterpoises is restored and the gates are raised.
>
> This arrangement has been practically applied ever since the year 1834, in the improvement of the Ouse above York. (Civil Engineering and Architects' Journal, 1840, III, page 284.)
>
> The Ouse was formerly navigable only as far up as Selby. Farther up to York the depth on several gravel-bars at low water was only 5 feet.
>
> To navigate this portion of the river it was, therefore, necessary to await the spring freshets, and the larger class of ships could not get up at all. After several of the gravel-bars had been removed by dredging a depth of from 11 to 12 feet was obtained at high water.
>
> After this it was decided to extend the navigation of the river 20 miles farther up, to Borough Bridge.
>
> A number of locks and dams already existed on this part of the river; but the depth of water in the intervening pools was not sufficient, and it was impossible to raise the dams on account of the low banks of the river. Nevertheless, at low stages in summer it was possible to raise the surface of the water 18 inches This purpose was subserved by the wicket arrangement just described.
>
> Two wickets of this kind, each 74 feet long, 18 inches wide and 4 inches thick, constructed of pine wood, constitute the movable portion for increasing the height of the dam, whose whole length is 148 feet. They stand upon the top of the massive dam, and are held at every ten feet by strong iron hinges, let into and fastened with lead to hammered stone, which permit them to lie flat on the top of the dam. The movable arm of each hinge ends in a pin 1 inch in diameter, which projects above the wicket. To these pins flat chains are fastened, which wind up on an equal number of eccentrics. The latter are attached to two iron axles, each of which has the same length as the corresponding wicket. These axles rest on iron chairs, which are placed on the up-stream slope of the dam. Next to each of the abutments a cog-wheel is attached to the axle. This cog-wheel is driven by another wheel, which latter is connected with a pulley from which the counterpoise hangs.
>
> When the counterpoise rests upon the abutment the wickets stand in a perpendicular position. This is the case as long as the water does not rise above 6 inches over the wickets, or 2 feet over the top of the dam. When the water rises above this point its pressure upon the wicket gains the ascendency; they lie flat upon the dam, and their influence upon raising the water is completely destroyed. As soon, however, as the water subsides, the counterpoise sinks, and the wickets resume their upright position. This arrangement was proposed and carried out by Engineer Rhodes, and it is said to have given results in every respect favorable.

Hagen then goes on to say:

> Another ingenious arrangement of such wickets on dams was executed by Engineer Thénard, on the River Isle, in the Department de la Dordogne. It not only possesses the advantage of the one just described, in that the shutter falls flat upon the top of the dam, but it possesses besides the superiority in this, that no chairs or other parts of the apparatus project, and that, therefore, the greatest ice-field can pass over it without causing any damage. The raising and lowering, it is true, is not caused by the rise and fall

of the water itself, but the attendant must, by means of a mechanism which he controls from the shore, sever certain connections. There is, however, no disadvantage in this, as the employment of an attendant is already necessary at that point on account of the lock. The movement of the shutter is caused, however, by the pressure of the water, and results at once, without the application of outside forces. These movable dams were partly constructed in 1828, and finished in 1832. In the report of the commission which examined them in 1841, no mention is made either of injuries or repairs, from which it must be inferred that such did not occur to any noteworthy degree.

Figures 8, 9, 10, and 11 show one of these dams, the elevation looking down stream, the plan, and two sections. The whole length of the dam is 151 feet; at one end there is a lock and two sluices. The dam is created by the down-stream shutters, which fall down stream. When they are raised, as figure 10 shows, they are held in position by iron props which abut against iron plates on the top of the dam. It is only necessary to trip these props, and the shutters fall down under the pressure of the water. For this purpose an iron rod (figure 12) is used, which extends lengthwise over the dam, and is provided with teeth at one end, which are grasped by a cog-wheel. This cog-wheel is put in motion by a lever which is attached to its axle. The props are not tripped at once, but in succession, a different one being tripped each time that the bar advances 1½ inches. This is accomplished by means of projections on the iron rod, whose distances apart are a little greater than the distances between the props. The drawing back of the rod before the shutters are again set up is accomplished by the same machinery.

The raising of the shutters against the pressure of the water would, however, be very difficult if this pressure could not be removed while doing so. The counter-shutters, which fall in the up-stream direction, are used for this purpose. They generally lie flat, both in high and low water, and grasp, by means of a spring-latch, a catch which is fastened to the top of a post in front of each. These latches can be moved in the same manner as the props which sustain the lower shutters. As soon as one of them is sprung the water from above raises the counter-shutter as far as the chains will admit. When all the counter-shutters are raised the water is dammed, and several minutes intervene before it flows over. During this interval the lower part of the top of the dam is dry, and the attendant has the opportunity, without the least danger, to descend by means of a ladder, and to raise each section of the dam in succession, replacing its prop in its proper position. The operation is begun on the side from which the attendant descends, and is continued to the other side. He then waits until the water flows over the upper edge of the counter-shutters, and the real shutters become the dam. As soon as this occurs the pressure ceases against the counter-shutters, and they can be easily and rapidly pushed down in succession by a pole, so that the spring-latches again grasp the catches and hold them firmly.

The commission which examined this construction on the Isle expressed the opinion that these shutters could safely be made from 3 to 4 feet high, but in the latter case it would be well to limit the length of the sections to 3½ feet.

Hagen then mentions that movable dams have been constructed which turn around vertical axes like lock-gates. The axis is placed either in the center of the gate or near it. They are maneuvered by means of valves in each leaf, assisted by machinery. The advantage is that as the gates are high the machinery for turning them can always be used. The disadvantages are that they can only be made of narrow spans: that, when open, they stand in the stream, and are exposed to destruction by ice and drift; and that, when closed, only the larger leaf can be supported, the pressure of the water having a tendency to move the other leaf away from any support that might be constructed for it.

He then mentions another form of movable dam; this consists in laying a sill in the bed of the river, and swinging, just above this, a beam from abutment to abutment, and then placing, by hand, small scantling, which he calls "needles," resting against the sill below and the beam above. This plan has been practiced in France for many years.

A great improvement on this plan was made by the French engineer Poirée a short time before 1840.

The improvement consists in this, that instead of having a single swinging beam for the whole span, this beam consists of different pieces resting upon movable trestles. The first dam of this kind is in the Yonne, just below the mouth of Bourgogne Canal, near the village of Epineau. Soon after (in 1840) a similar dam was built in the

Seine, near Paris. The result of both, so far as it is known, seems to have been satisfactory in every respect; and since that time they have been erected in many other streams in France, with frequent alterations, however, in their construction.

The following is a description of the first one erected, (near Epineau:)

The movable portion of this dam is 223 feet long. Its masonry-floor has (as Fig. 13 shows) a width of nearly 32 feet, and is 15¼ inches below the lowest stage of water in summer. The floor is about on a level with the natural bed of the river. The masonry of the floor is on an average about 4 feet thick. A recess, 7 feet and 3 inches in breadth, extends lengthwise along the floor. In this the wooden frame which supports the movable iron trestles is laid and firmly wedged.

The whole arrangement is shown in figures 14, 15, and 16. The edges of the recess are not vertical, but inclined, the width on the bottom being greater than on top. On the down-stream side a wooden sill of corresponding form rests against the edge of the recess. The rest of the recess is then filled by a horizontal wooden frame, which is bound together at intervals of 3 feet 2 inches from center to center by braces mortised and tenoned into it. In the space between the sill and this frame double wedges are driven at intervals of 6 feet 6 inches, by which the whole wooden frame is held in the recess.

This manner of fastening is so simple that it is not necessary to draw off all the water in order to take out or replace the frame. According to Chanoine, this can be done without difficulty in a 3-foot stage of water.

In later constructions the sill is entirely abandoned, the down-stream side of the recess being made vertical and of cut stone, so that the frame may be firmly wedged against it.

On the inner side of the longitudinal beams of the frame, and immediately over the center line of each brace, are laid the iron collars wherein the axles of the trestles turn. These collars are so arranged that the trestle may be taken out and replaced under water. Figure 17 shows the elevation of the up-stream collar. It is simply supplied with a round hole into which the axle is inserted. The opposite collar, however, (Fig. 18,) has, besides the hole in which the axle lies, a slot at one side enlarging upward, down which the axle must be shoved, and which is then closed by an iron plug. The iron trestles do not, however, rest entirely on these collars, as their axles touch the braces just below them, and a part of the weight is borne by the latter.

The trestles, nearly 7 feet in height, are constructed of bar-iron, jointed and riveted, except the upper end of the strut, which is held by a screw. The bar-iron is 1¼ inches in thickness, and also in width. The weight of each trestle is such that two workmen standing on the foot-bridge can easily raise it by means of the chain. This chain is fastened to the ring which projects from the head of the screw above referred to. But this chain is in no wise indispensable, for an experienced workman can easily grasp the upper beam of the trestle and raise it into position. It is, therefore, customary during winter to remove the chains, because they are frequently caught by drift, and then are not only subject to injury themselves, but are apt to retain such objects at the dam, and cause heavy deposits of gravel.

In constructing the dam, each trestle is raised by the attendant and his assistant; as soon as it is nearly vertical, and only moderate strength suffices to hold it, the attendant leaves this part of the business to his assistant and seizes the trestle at the upper bar with the forward notch of the hook, (Fig. 19,) and then places the rear notch upon the last trestle raised, which is now firmly established. The foot-bridge is then extended by laying three short planks, about 4 feet in length, alongside of each other, and so far forward that they have a firm hold upon the newly-raised trestle. Through a notch in the planking a strong pin fastened to the upper bar of each trestle extends above the floor. This is partly to serve as a guide for properly laying the planks, but mainly as a firm point against which the attendant can brace his foot during the operation of raising the next trestle.

As soon as the planks are laid, two iron clamp-bars, one inch in thickness and nearly two inches in width, provided with two notches, (see Fig. 20,) are laid upon the last two trestles, after which the hook which temporarily held the last trestle in position may be removed. One of these iron clamps is laid on the up-stream side of the heads of the screws, and forms the upper bar against which the "needles" or scantling rests. The other, which need not be so strong, and is often entirely omitted, rests, if it is used at all, upon the down-stream corner of the trestle.

In this manner the whole of the frame-work may be erected by two men, although it is generally customary to employ a third laborer to carry the planks and the clamps. The removal of the dam is carried on in the inverse order, and needs no description. It must be remarked, however, that it is not necessary to raise up or lower all of the trestles, as each one, when it once has its full connection on one side, is perfectly safe. It is, therefore, quite easy to make an opening at one end of this dam for passing vessels. The last trestle lies as flat as the rest in an opening provided for that purpose in the massive abutment.

Iron bars, projecting above the floor of the bridge, are fastened on the outside to the top of the posts of each trestle; but, in order to preserve clearness, they have not been indicated in the drawings. The one on the up-stream side is only a few inches high, and serves partly to prevent the clamp-bar from clipping off, and partly to hold the last "needle" in case this trestle becomes the end of the dam. The iron bar at the other side rises about one foot above the foot-bridge, and is also partly for the purpose of holding the other clamp-bar, but mainly to serve as a rest against which the "needles" are piled during the course of constructing or removing the bridge.

The "needles" are made of straight-fibered wood, and are 7 feet 9 inches long, 2¼ inches broad, and 1½ inches thick. They rest at top against the clamp-bar above mentioned, and at bottom against the up-stream longitudinal beam of the frame, into which for this purpose an iron bar is let. In front of the axle of each trestle this iron bar has a small projection, which holds the lower end of the "needles" in the same manner as the top is held. The attendant thus has a guide at each trestle, by which he can keep the "needles" in the proper position.

The cost per running foot of this dam, including foundations, abutments, and all appurtenances, was 175 thaler, ($128.) After a few attempts it required 32 seconds per running foot to take down the dam, and 57 seconds per running foot to erect it. But it was soon shown that the work was done more rapidly as soon as the attendant had more experience.

It is undoubtedly a question of great importance to ascertain how this dam will act during high-water, and whether it will not cause large deposits of sand, which will make it difficult to raise the trestles, and therefore necessitate the resort to extraordinary measures for this purpose. From all information which has become public, and from what could be learned from private inquiry, it seems that these fears are unfounded. Chanoine says that it is true that the recess is sometimes filled up with deposit, but that even then the trestles can easily be raised or lowered if they are first worked up and down a little, so as to loosen the deposit, and cause the current to carry it off. The deposit that remains in the recess is, according to the same authority, easily removed by forcing a rapid stream of water over it, and for this purpose the dam itself furnishes every facility. It is only necessary, after the dam is constructed, to remove a few of the "needles" at the point where the scouring is to be done. In this manner there is no difficulty after the whole structure is erected in completely cleaning the foundation and recess. Even if the trestles were found so completely covered that they could not be lifted by either the chain or hook, the proximity of the already constructed portion of the foot-bridge would allow the easy removal of the deposit by hand-scrapers, and thus permit the trestle to be raised.

It is besides probable that in such a case this difficulty would be removed by putting the "needles" in place as far as the foot-bridge is constructed, as by this means the rapidity of the current would be so much increased that it would remove the deposit from the trestles that were buried. The conditions are precisely the same as in building a wing-dam, or dike. The portion of the dam already erected is nothing but a perpendicular wing-dam with a very steep face, and precisely as such a work under other circumstances causes a great scour at its outer end, so in this case will it remove the gravel and sand from the foundation of the dam.

In some instances, as in the Saône, between the Rhine-Rhone Canal and Lyons, the arrangement just described does not form the entire dam, but is only an addition to the permanent structure, which in this case rises to ten inches above the lowest stage of water. (*Annales des Ponts et Chaussées*, 1845, I, page 10.) In this arrangement there is undoubtedly no trouble with deposit, or at furthest only with that which the recess contains. But even this cannot occur here, as the foot-path consists of iron plates fastened to the upper bar of the trestles in such a manner that it lies down with the trestles, and thus makes a cover which effectually closes the recess and conceals the whole apparatus. The details of this arrangement are thus far unknown.

A great advantage of this dam is that the stage of water can be kept at any point in case of rises by simply removing a proper number of needles. It is advantageous, however, not to make this opening at one point alone, but to make numerous openings uniformly distributed along the whole dam. The attendants are able to judge with great accuracy in this matter, so that it is not necessary for them to make continual experiments, but they are immediately able to tell how many needles it is necessary to remove for any rise.

When the water below the dam is high, with a strong wind up stream, there is danger that the waves may lift the foot-path from its position and carry it away. This evil is averted by drawing the chain diagonally across the foot-bridge between the successive trestles.

The erection of the trestles and the placing of the "needles" does not generally require haste, as the low-water stage of rivers and streams generally comes gradually. On the other hand, rises, especially in mountain streams, (where these dams are generally used,) often occur suddenly, in which case the arrangement just described for removing the "needles" is not as rapid a maneuver as the circumstances require.

This is particularly the case when the rise occurs at night, because then the work is delayed by darkness. Provision for the convenient and safe use of lanterns must naturally be made, but the lifting out of the "needles" may be avoided, and the stream may be made to push down the sections between the trestles, if the iron clamp-bar is arranged in the same manner as the turning-beam above described. This arrangement is made at the dam in the Seine at Saint Morton. (*Annales des Ponts et Chaussées*, 1843, I, page 250.) Each needle is provided with a strong ring at its handle. A line is tied to the ring of the "needle" next to each trestle, and passed through the rings of every "needle" in that section and then fastened to a strong hawser which reaches the whole length of the dam. In this manner all the "needles" remain hanging in bundles when the trestle is lowered, and as only one end of the hawser is fastened they are driven against the bank; afterward they are easily loosened and carried to the store-house.

The clamp-bar must be arranged differently from the manner above described if it is to be loosened when the "needles" are still pressing against it. The arrangement is quite complicated, and is made more so by the necessity of guarding against all accidental or malicious movements which would result in the opening of the dam. I will describe here only the material part of the arrangement. Figs. 21, 22, 23, and 24 show it in plan, and in front and side elevation. The clamp-bar has, in every instance, a hook 2¼ inches broad and 1 inch high. At one end it is provided with a hole, through which passes a pin which projects above the trestle. At the other end the hook is bent into a cylindrical form, which grasps the pin on the trestle. The front side of the hook forms an even surface, against which the "needles" rest.

To prevent the hooks from being loosened by the pressure of the "needles" there is an eccentric disk, which turns around the shank of the ring previously mentioned, to which the chain for raising the trestle is fastened. Figures 21, 22, and 23 show the eccentric disk in the position in which it holds the hook. In Fig. 24 it is turned so far that the hook no longer takes hold and the trestle may be laid down. Before the eccentric is turned into this position the trestle must be held by the light hook (Fig. 19) until the foot-bridge can be removed. The position of the eccentric disk is finally fixed by a key, which must be raised whenever it is to be turned. If the latter is in such a position that the eccentric disk is clear, as is shown in Fig. 24, a blow on the point of the disk will cause it to turn, and the pressure of the "needles," which is transferred to the hook, will complete it. The hook, however, is removed before the trestles are allowed to fall.

Finally, it must be stated that the abutments at St. Morton are not provided with recesses, but that the last clamping-bar, whose length is equal to the height of a trestle, turns on a vertical axis and is held in its position by a brace. It rests flat against the wall when the dam is lowered.

Becker also speaks of the great importance of movable dams, and then gives a description of several kinds already constructed, all of which, except one, are given by Hagen. This one is a combination of the systems of Thénard and Poirée. He says:

The systems of Thénard and Poirée can be combined with advantage to form a system peculiarly adapted for sluices which must be rapidly opened, or which are regulated by the water itself and need no attendance. Figs. 25, 26, 27, 28, and 29 show the construction of such a dam as it is built across the Seine, at Courbeton, in the vicinity of Montereau. A needle-dam, 124 feet 8 inches in length, abuts against the tail-wall of a lock. To carry off the surplus water in high stages, a sluice 39 feet 4 inches wide suffices. This sluice was, therefore, built according to this mixed system, and is separated from the needle-dam by an abutment 3 feet 3 inches thick.

When the sluice is closed, the shutters, Figs. 26, 28, and 29, are raised, and the iron trestles of the dam are also raised, and serve as support for the planks of a foot-bridge. The needles are not used.

When the water rises it flows into a culvert in the shore abutment, and thence to a small water-wheel 5 feet 3 inches in diameter and 20 inches wide. (Fig. 26.) On the axle of this wheel there is a bevel-wheel, which works into another bevel-wheel, on whose axle there is a rectangular cog-wheel which works into another wheel, whose axle is vertical and reaches down to the foundation of the dam. At the lower end of this axle there is another cog-wheel, which works into the toothed end of a rod, (Fig. 27,) whose motion, in a longitudinal direction, causes the successive falling of the shutters.

As soon as enough shutters have fallen to reduce the water to its former height, the water-wheel stops, and no further opening of the sluice takes place.

At high-water the effect of the water upon the water-wheel only ceases when all the wickets are down.

From this it is easily seen how the stage of water regulates itself, and prevents a flow over the top of the needle-dam.

If it is desired to raise the shutters after the subsidence of the flood, the lock-tender places the "needles" in position, and thus constructs a protection, behind which he can raise all the shutters, with ease, by hand.

After the shutters are all raised the "needles" are again removed, and the planks of the foot-bridge replaced, in case they were removed during the high stage of the water.

Should the water-wheel remain in motion longer than is necessary for the complete movement of the iron rod, there is an arrangement attached to the mechanism by which the pinion that moves the rod is thrown out of gear. (Annales des Ponts et Chaussées, 1851-'52.)

METHODS IN USE IN INDIA.

The arrangement of double shutters, shown in Figs. 8, 9, 10, 11, and 12, has been successfully used in Orissa, in India, on the anicut or dam across the Mahanuddy River at Cuttack. The following description is taken from the Roorkee Treatise on Civil Engineering, volume ii, paragraph 703:

> Instead of the small sluices provided as in the Kistna, and other anicuts, a larger kind of sluice, on the French pattern, has lately been successfully employed on the Mahanuddy anicut in Orissa.
>
> The center sluices are divided into 10 bays of 50 feet each, by piers of masonry. Each bay is closed by a double row of timber-shutters, which are fastened by wrought-iron bolts and hinges to a heavy beam of timber imbedded in the masonry floor of the sluices. There are seven upper shutters, and seven lower or rear shutters; the latter are 9 feet in height above the floor, and the former 7½ feet.
>
> During floods, therefore, the upper row of shutters, which fall forward, is fastened down by clutch-gearing in an almost horizontal position, while the rear set of shutters, which fall backward, is kept during flood in a horizontal position by the water rushing over.
>
> During the summer season these rear shutters have to do the duty of damming up the water, and for this purpose they are provided with strong wrought-iron stays or struts attached to them behind or on their lower side. As it would be almost impossible, however, to lift these back shutters with a depth of 5½ feet of water tearing over them, the upper shutters are so constructed as to render this a matter of comparative ease. As the upper shutters point up stream, the natural tendency of the powerful current passing over is to lift them up. By simply unclutching them, therefore, they immediately rise and dam up the water, being retained in position by two sets of chains, which take the strain off the hinges. The water being thus dammed up, the back shutters are easily lifted, and permit in their turn of the upper shutters being lowered forward into their horizontal position.
>
> The superintending engineer, Mr. Walker, in reporting on them, considers it is established—
>
> 1st. That, with the shutters constructed on the French pattern, and with a head or pressure of between five and six feet, 500 linear feet of shutters can be easily lowered in one hour.
>
> 2d. That, under the same condition, an equal length of opening can be closed in 25 minutes. In closing, the shutters may be said to be self-acting.
>
> 3d. That when the back-stays are released, the falling shutters are received upon a cushion of water in time to prevent any undue concussion.
>
> 4th. That the action of the water in lifting the upper shutters brings no excessive jerk on the chains, but that it is advisable that chains have an adjusting-screw fitted on, so as to make the strain perfectly uniform. The shutters were brought home in a current of 10 feet per second.
>
> 5th. That three men can knock away the back-stays with a pressure of between five and six feet with ease and security.
>
> 6th. That twelve men are necessary to lift each of the back shutters into position.

An immense dam, two and one-third miles in length, is now in process of construction across the Soane River at Dehree, where it emerges from the Kymore hills and enters the plains of Behar, through which it flows sixty-five miles to its junction with the Ganges. At each end of the dam, and at its middle, under-sluices are provided in order to prevent an accumulation of alluvial deposit above the dam. Those at the ends are especially designed to keep clear the heads of the irrigation-canals which start at each bank, and take their water from the pool formed by the dam.

The sluice-gates are to be made on the double-wicket plan, with some modification, and the following description is taken from the London Engineering, vol. xvi, p. 219:

> We proceed to give a short description of the self-acting shutters invented by Mr. Fouracres, which are used to open or close the under-sluices in the wear. We have already stated that there are three sets of sluices, of 25 openings, of 20 feet in each set, and that only in times of flood, and in order to scour out any deposit which may be formed opposite the lock-entrance on either bank, are they required to be opened. The usual practice in works of this kind is to have small openings of six feet in width, with a roadway overhead. the openings being closed or opened by gear from the top, but it was found by thus diminishing the size of the passages, the efficiency of the scour was also considerably diminished, and moreover openings of that size were unable to pass through them all the large timber, wrack, and brushwood which an Indian river brings down in times of high flood. It was therefore attempted, in Orissa, to increase considerably the size of the sluice-openings in the wear in the Mahanuddy River, and shutters on the plan adopted by French engineers in the navigation of the Seine were constructed.
>
> * * * * * *
>
> The objection to this plan was that the upper shutter was raised by the stream with such velocity and force that the chain-ties supporting it frequently gave way, and the shutter was carried off its hinges. It was also necessary that the shutter should be self-acting, as to opening itself to let a flood pass through the sluices, and it was to meet these two requirements that Mr. Fouracres's self-acting shutters were invented. Figs. 30, 31, and 32 show three views of these shutters in different positions, and Figs. 33 and 34 show two sections which will further assist in explaining the arrangement.
>
> Fig. 30 shows the sluice "all clear," with both shutters down, lying on the floor, the floods being supposed to be running freely between the piers, which are 8 feet in height. When it becomes necessary to close the sluice, and shut off the water flowing through it, a clutch worked from a handle from the top of the pier is turned, which frees the shutter from the floor, and it then floats partially up from its own buoyancy, when the stream, impinging under it, raises it to an upright position with great force, shutting up the sluice-way. But if a shutter 20 feet long were allowed to come up with such pressure it would either carry away the pier or be carried away itself. To destroy this shock, Mr. Fouracres has contrived six hydraulic buffers or rams, which also act as struts for the shutter when in an upright position. These rams are simply pipes with a long plunger inside; (see enlarged section, Fig. 35;) the pipes fill with water when the shutter is lying down, and when it commences to rise the water has to be forced out of them by the plunger in descending, and as only a small orifice is provided for the escape of the water, the ascent of the shutter forced up by the stream is slow and gentle, instead of being violent.
>
> The water is now shut off effectually, as shown in Fig. 31, but, without other means being taken, it would be impossible to open the sluice again, as it could not be forced up stream. Another shutter is therefore provided below it, as shown in Figs. 32 and 34, this lower shutter being arranged so that it can be lifted up by hand and placed upright, as shown in Fig. 32. The water is then allowed to fill the space between the two shutters, and the upper one can then be thrown down on the floor again, but the lower one is held up by ties which are hinged to it at one-third of its height, and by this means it is balanced, and resists the pressure on it until the water rises to its top edge, when it loses its equilibrium and falls over, thus opening the sluice again. The shutters can be left to fall of themselves if the river rises in the night, or, if it is not thought expedient to let them fall, they can be made fast by a clutch on the pier-head, as shown. By these expedients these large sluice-ways, 20 feet broad and 8 feet deep, can be shut off or opened as required, with the greatest facility and expedition, and the whole set of 25 sluices can be opened in a few minutes, and when opened they can pass through them anything that the river brings down without danger to the wear. It has been proposed to bridge over the piers with a light iron foot-bridge to enable a man to work the clutches of the shutters more easily.

It will be seen from the above that in the sluices of the Mahanuddy dam the openings are 50 feet in width, and are closed by seven shutters of each kind, giving a width of a little more that 7 feet to each shutter, while in the Soane dam each opening is 20 feet wide and is closed by a single shutter.

CHANOINE WICKETS.

In the *Annales des Ponts et Chaussées, tome* 2, 1861, there is a very complete memoir on one kind of movable dams, prepared by MM. Chanoine and De Lagrené, of the Corps des Ponts et Chaussées. This memoir gives a full detailed description of what is known as the Chanoine system of wickets.

It should first be stated that the dams, principally on the Seine and Yonne, to which these wickets have been applied, consist of a lock, a pass for navigation whose sole is about even with the bottom of the river, a pier, a weir whose sole is about 3½ feet above the river-bottom, and an abutment.

The Chanoine wickets are shown in Figs. 37 to 45. Figs. 37, 38, and 39 represent the wicket of a navigation-pass; Figs. 40, 41, and 42 the wicket of a weir; and Figs. 43, 44, and 45 show the manner of raising the wickets by a boat, provided with a windlass and other suitable equipments.

The Chanoine wickets are of two kinds, automatic for the weir and non-automatic for the pass for navigation, or chute. They differ from the shutters previously described in having the axis of rotation at from one-third to five-twelfths the vertical height from the foot of the wicket. This axis is supported by a small iron horse, which is itself movable up and down stream around its foot. The head of the prop rests on a pin, passing through boxes fastened to the cap of the horse, and its foot rests against a heurter. To throw down a wicket the foot of the prop is pushed away from the heurter by the projections of an iron rod worked from the abutment. These projections are so spaced that the wickets are thrown down in succession. This arrangement is adopted from the Thénard system, which has already been described. To permit this movement, the hole at the head of the prop is larger than the pin which connects it with the horse.

The wickets for the navigation-pass are hinged at five-twelfths the vertical height from the bottom, and are provided with a fixed counterweight at the foot. In vertical height they vary from 8 feet 10 inches to 10 feet 2 inches, and when in position are inclined down stream under an angle of 15°. The portion of a wicket above the axis of rotation is called the *chase*, and that below the axis the *breech*.

The wickets of the weir are smaller than those of the pass, and are hinged at about one-third the height above the bottom, so that when there is a flow over the top of more than 8 inches in depth, the pressure above the axis of rotation exceeds that below it, and the wicket swings into a position nearly horizontal, thus opening a passage for the water. The weir-wickets are provided with movable counterpoises, in addition to the fixed ones, with the expectation that after being swung they will close of themselves when the water recedes. As will be found further on, this arrangement did not work satisfactorily. These wickets, like those of the navigable pass, could be tripped by an iron rod, worked from the abutment, whenever a great flood made it desirable to throw them down flat, on the top of the weir. It was not thought desirable to make the wickets of the navigable pass automatic for fear lest they should be thrown down by floating bodies, which might become entangled, and, by preventing the wicket from lying flat, make a dangerous obstruction to boats.

The wickets of the weir varied in height from 5 feet 5 inches to 6 feet 7 inches, and their axes were placed about an inch and a half higher than one-third the total height above the sill. All wickets are made about 4 feet wide to facilitate maneuvering.

To raise the wickets a boat 30 feet long and 8 feet wide was used, which was worked from above the dam, and was provided with ropes, fenders, and windlass. To raise the wicket nearest the bank the boat was placed along the upper side of the abutment, at right angles to the current, with its bow projecting half the width of a wicket. By means of a boat-hook the attendant seized the handle on the lower end of the wicket. As soon as this was done his assistants commenced winding in a rope, fastened to the lower end of the boat-hook, and passing thence around a pulley in the bow to the drum of the windlass. The wicket was thus raised into a horizontal position, and the current pressing down on the breech swung it into place. As soon as one wicket was raised the boat was pushed forward the width of a wicket, and the operation was repeated until the pass was entirely closed. There is always an interval between the wickets of a little less than two inches, and by inserting keys in the intervals between the wickets already raised, and by using fenders and a cable fastened to the abutment the boat is securely held in place throughout the maneuver. The wickets of the weir are raised in the same way.

COMPARISON OF THE POIRÉE, CHANOINE, AND DESFONTAINES SYSTEMS.

In tome xi, *Annales des Ponts et Chaussées*, 1866, M. de Lagrené, engineer des Ponts et Chaussées, makes a comparison of the different methods of constructing movable dams, and the following is an abstract of his article:

> At the present moment dams are in course of construction, not many miles apart that differ essentially; thus on the Seine, below Paris, the needle-dam, invented in 1833 by Inspector-General Poirée, has been adopted; above Paris the dam with movable wickets, invented in 1852 by Chief Engineer Chanoine, has been chosen; while on the Marne the movable dams of the Upper Seine are used, but under different conditions, and with the addition of the drum-wickets invented in 1864 by Inspector-General Desfontaines.

These three systems are those which he compares. As the Poirée needle-dam has been fully described already, also the Chanoine wickets, only his conclusions will be given in regard to these two systems, but a full description will be given of the Desfontaines drum-wickets, (*hausses à tambour.*)

The Poirée needle-dams were first designed for heights of 5 feet, but they have gradually been heightened to 10 feet 10 inches.

> And as, in fact, a dam on any system whatever is always an obstacle to navigation, it was natural to limit their number as much as possible, and, in consequence, to give to each one the greatest height compatible with its location and details of construction.
>
> It will at once be understood that if a sudden flood should come, or even a simple artificial wave, the foot-bridge for managing a needle-dam might be submerged before there was time to remove the needles, and serious accidents might happen either to the dam, to navigation, or to riparian property. An endeavor was made to avoid this danger by means of a permanent weir connected with the pass, having a needle-dam; thus at the Epineau dam, whose pass is 230 feet wide, with a sill 16 inches below low water, M. Poirée added a masonry weir 403 feet long, raised to 3 inches below the leve of the pool; at the Bezons dam, consisting of an open pass 158 feet in length, with its sill 2½ feet below low water, and a higher pass 155 feet in length, with its sill 16 inches below low water, a permanent weir has been added 1,411 feet in length, and at an elevation of 16 inches below the level of the pool; but such a weir, admissible for small lifts, becomes very costly when the lifts are great. Moreover, in certain cases, the submersion of the needles and trestles can still occur in spite of it.
>
> To diminish the danger of submersion, while at the same time avoiding the cost and inconvenience of a permanent weir, and also to facilitate navigation by artificial waves, the bars that support the needles have been arranged so that the lock-tender can easily disengage them. The needles of each bay are then carried away by the current, as the lock-tender successively opens the bays; but as the precaution is taken to fasten them to ropes, they are easily fished up from below the dam.

At the dams on the Yonne the escapement consists of an eccentric which permits the opening of 131 feet of pass in 15 minutes, while an hour used to be required with the old arrangements.

The Belgian method allows the needles of each bay to escape in a body, but the trestles remain standing. The French method drops each trestle as the needles attached to it are loosened. By the Belgian escapement the heads of the needles must pass under the sheet-iron floor of the foot-bridge. The disadvantages of this arrangement will be shown presently. The employment of escapements does away with the necessity of raising the needles by hand, and thus permits the construction of higher dams.

METHOD OF MANEUVERING A NEEDLE-DAM.

Let us recall in a few words how a needle-dam, furnished with escapements, but without permanent wear, is managed.

Suppose it to be entirely closed. If the discharge is nearly that of low water, the filtrations between the needles can be reduced by throwing in grass just above them. If a rain should come sufficient to raise the level of the pool, the attendant makes a sufficient number of openings in the part of the dam farthest from the lock, by removing only a few needles from each bay, so as to divide the issuing current. As the discharge diminishes, the attendant gradually replaces needles that have been removed. When the rainy season approaches, the dam is prepared for opening. With this view he passes the ropes through each group of needles yet remaining between the trestles, and fastens them to the shore in the customary manner, and as soon as the lift of the dam is reduced to a height determined beforehand, he looses the escapements and lowers the trestles in succession, satisfying himself as he goes on that each one is well down and makes no projection on the floor. The same method of opening is used on the arrival of an artificial wave on the rivers where this method of navigation is in use. This maneuver must evidently be made at night as well as during the day, and, besides, the trestles must be laid down in winter, as soon as the first ice-cakes form. When the opening is completed the attendant can fish up at his leisure the needles which are floating below the dam at the end of the cable.

When the high-water season is passed, the attendant piles up the needles upon the walls, and prepares to raise the trestles; this raising is done when the water-surface has fallen to a previously determined level; the attendant then raises all or part of the trestles, places a few needles at intervals, and gradually increases their number so as to obtain and preserve the normal level of the pool.

OBJECTIONS TO NEEDLE-DAMS.

A needle-dam is evidently, as has been already shown, a work by means of which the level of a pool is regulated at will, and very simply, by removing or adding a certain number of needles, provided always that the placing and the removing or loosing of these needles cause neither danger nor too severe an exertion. It, therefore, seems to us that when the height of the lift is slight, these conditions are only partly fulfilled, and that they are not fulfilled at all when high trestles are in question. This is the case which we propose examining.

When the trestles are more than 8 feet high the needles assume such dimensions that their transportation from the store-house to the place where they are used is quite burdensome, (the Bezons needles are 13 feet in length and 3 inches square,) and their placing becomes dangerous and difficult, as much on account of their length and cross-section, as in consequence of the depth of the water, and its velocity. If a needle does not strike the sill against which it ought to abut, the attendant may be dragged overboard by it. Their removal by hand becomes impossible if the difference of level is great, and it is then necessary to resort to a system of loosing the supporting-bars, or to pull the needles one by one by means of a windlass. (A needle 13 feet long and 3 inches square weighs 20 lbs. when it is dry, and 29¼ lbs. when it has remained in water.)

Throughout the work of placing or removing needles or opening by escapement, the attendant is obliged to be on a narrow foot-bridge, and while there to use considerable exertion above a rapid current, no matter what the weather, and as often at night as by day; his work is certainly very dangerous.

Careful watching is necessary, at least at certain times and for certain rivers, for the least negligence may cause the submersion of the dam, and result in serious damage.

As soon as the work of removing the needles of a dam is begun, the current sets toward the bays that are wholly or partly open; its strength increases with the number of needles removed, and if the pass is near the lock, boats may miss the entrance and be drawn against the trestles.

The removal of the needles, even if only partial, ends, at last, even when the openings are wide, in causing scour below the pass. This scour is much more surely produced if the dam is turned into a spur-dike, as is the case when a number of bays are entirely opened, either by escapement or by successive removal.

When a trestle is laid down, the attendant determines by means of a mark on its connecting-chain if it is well on the bottom. This verification can be done with sufficient accuracy when the depth of water is not great; but if the depth exceeds 6½ feet, it becomes very difficult, and is often deceptive.

The trestles, even if they are perfectly lowered, remain entirely uncovered; they and their chains may be struck by a boat dragging on the bottom or by a log badly fastened under a raft, and they are still more exposed to these injuries if they are badly bedded. Moreover, it is very difficult to be sure that the trestles and their chains do not project slightly.

To sum up, needle-dams are liable to the following objections:

1. Difficulty in placing and removing needles when the trestles are higher than 8 feet.
2. Danger to the men obliged to work on the foot-bridge, which increases with the weight of needles and the difference of level.
3. Scour at the foot of the pass; that is, at the foot of a delicate and costly work, and which is to be dreaded in proportion to the amount of fall.
4. Currents near the head of the lock, or near the channels for navigation, where there is but one pass.
5. Continual watchfulness at certain times, and danger of submersion.
6. Difficulty of accurately bedding the trestles when they are high.
7. Unhealthfulness produced by the stoppage of floating bodies.

If a long, permanent weir is connected with the dam the danger of submersion or of scour diminishes, but the cost is great.

MOVABLE DAMS ON THE UPPER SEINE.

The first step towards the present Chanoine wickets was the Thénard system of double shutters. This worked very well for small lifts, but was unmanageable when the lifts were increased. An effort was made to get additional working-power by establishing above the shutters a service trestle-bridge and by using a traveling windlass; but this did not entirely remedy the difficulty, as the system of hinging was such that enormous power was always required to raise the last shutters. This defect in the position of the hinge caused M. Chanoine to try the effect of putting it near the middle, and of supporting the axis by a horse, that was itself movable around its sill. As these wickets have already been fully described, it will not be necessary to repeat the description.

M. De Legrené sums up the advantages of the Chanoine wickets as follows:

1. Possibility of increasing the heights of dams.
2. Safety and ease of maneuvering.
3. Automatic regulation of the level of the pool.
4. Removal of the force of the current from the vicinity of the head of the lock, and of the channel.
5. Scour only to be guarded against below the weir.
6. Repairs easily made and seldom necessary.
7. Absence of obstacles to the passage of floods.
8. Facilities afforded to the method of navigating by means of artificial waves.

The details of the system constructed on the Upper Seine and Yonne will be given further on in an extract from the latest reports on these dams.

MOVABLE DAMS ON THE MARNE.

The number of locks and dams built for the improvement of the navigation of the Marne, between Epernay and Meaux, is twelve, but the description which we are about to give only applies to the eight built in 1863, 1864, and 1865, which are named as follows: Mont-Saint-Père, Azy, Charly, Méry, Courtaron, Saint Jean, Iles-les-Meldeuses, and Basses-Fermes; this last being situated a short distance above Meaux.

Of the four others, two are needle-dams, and the other two, (Damery and Courcelles,) which have wickets, and were built in 1853 and 1862, differ a little from the last eight.

Each dam on the Marne overcomes a fall of nearly 7 feet, and consists of—[Fig. 49]

1. A submersible lock 25¼ feet in width and 167 in length, between miter-sills, which is placed on the bank used for towing.
2. Navigable pass with swinging wickets, [Chanoine.]
3. A weir provided with drum-wickets, [Desfontaines.]
4. A pier, an abutment, and other accessory works with which we have no concern at present.

Each navigable pass has 82 feet of opening, and is provided with 20 wickets, like those used for the navigable passes of the Upper Seine. Each wicket has a width of four feet, and a height which varies according to the dam, from 8 feet 8 inches (Iles-les-Meldeuses) to 10 feet 2 inches, (Mont-Saint-Père.) The sill of each pass, placed at first at 2 feet below low-water, has been raised to 21 inches below low-water, by placing a cover 3 inches thick upon the original sill, with the view of better protecting the wickets when they are laid down. The space between two adjacent wickets is 2 inches; when the wickets are up, their tops are 2 inches below the normal level of the pool: consequently they permit an overflow 2 inches deep when the pool is at this level.

On the up-stream side of the 20 wickets of each pass are placed 20 trestles, from 8 feet to 8 feet 10 inches high, which work is a recess in the floor. These trestles have a triple object, that is:

1. To support a first service-bridge, raised from 5 feet 6 inches to 6 feet 4 inches above low-water, and upon which rolls a windlass for raising the wickets.
2. To receive after the closing of the pass an increase of height from 2 feet 7 inches to 3 feet 4 inches, so that the floor is thus raised 20 inches above the pool, and forms a communication between the lock and the pier.
3. To serve in case of need as a support for needles, and to form a Poirée dam. The dividing the trestles into two parts, one placed on the other, is doubly advantageous; in the first place the trestles are shorter, and in consequence the necessary interval between the last trestle and the pier is less, as also the recess to be made in the latter to receive the top of the trestle, and finally the first service-bridge can be nearer the water-surface, so that the chains of the wickets can be pulled under an angle more favorable for lifting them.

Each weir is 162 feet long, and is composed of a fixed and a movable part; the fixed part consists of a mass of beton faced with masonry, poured between two lines of piles and sheet-piles, with 25½ feet interval between the lines. This mass rises to 3 feet 5 inches below the level of the pool; or, which is the same thing, to an average height of 3 feet 11 inches above low-water. This fixed part is surmounted by 33 movable wickets, 4 feet 11 inches wide, with their tops, when they are up, at 3 feet 3 inches above the permanent portion; that is to say, at 2 inches below the level of the normal pool. These wickets, designed by M. Desfontaines, and which we have designated as drum-wickets, (*hausses à tambour*,) are still very little known; they therefore require a detailed description, the elements of which are found in the explanation attached by the inventor to the model sent to the London Exposition in 1862. These wickets are shown in Figs. 46, 47, 48, 50, and 51.

The object of M. Desfontaines was to utilize the power caused by the fall at each dam in such a manner that, in order to maneuver by means of it, the attendant would only have to direct its action in a simple and an easy way. The solution appears to us as complete as it is ingenious. The following is quoted from the above-mentioned notice:

"The moving apparatus consists of a series of gates, independent of each other, and turning around a horizontal hinge placed in the middle. The upper half is the *wicket*, properly so called. It is this which makes the pool. The lower half, which we will call the *counter-wicket*, has no other function than to carry along the wicket in the movement impressed on itself. It is inclosed in a quarter of a horizontal masonry cylinder, of the same length, whose axis coincides with the hinge, and in which it can consequently make a quarter of a revolution. The horizontal limiting surfaces of this quarter of a cylinder, or, if it be preferred, of this drum, do not pass exactly through its axis. One of them, the horizontal one, is slightly raised parallel to itself, and the other, the vertical one, has been similarly moved back, so that they leave empty spaces between them and the counter-wicket when it is in its extreme positions. The latter has also been slightly bent downward, in order to diminish the raising of the horizontal bounding surface, and thus prevent it from masking a part of the wicket. Finally, the ends of the drum are closed by two sheet-iron partitions, in which two rectangular openings have been made, corresponding to the empty spaces which have just been mentioned."

The successive drums, thus provided with their wickets and counter-wickets, are made in the body of the weir. They rest upon the béton contained in the inclosures, and are in close contact with each other.

"If we now consider the whole body of drums, we see that by their union they form below the crest of the weir and along its whole length a single tube, resting at one of its ends against the face of the pier, and at the other against the face of the abutment, and divided by the counter-wickets into two longitudinal compartments.

"In the pier itself, just above and below the line of the drums, two vertical wells are made, which communicate by culverts, one with the upper pool and the other with the lower pool, and these two wells also communicate with each other by means of two horizontal cast-iron pipes built into the masonry, and closed at each end by valves. These pipes fork in front of the openings made in the sides of the drums, and, passing through the pier, connect with these openings in such a manner that one connects with the up-stream compartment and the other with the down-stream one.

"This settled, if we suppose the four valves in the pier closed, all the wickets laid down on the floor of the weir, and consequently all the counter-wickets horizontal, and if we then open the up-stream valve of the pipe corresponding to the up-stream compartments of the drums, the water of the upper pool will immediately fill this compartment, and will then press on the counter-wickets with a force corresponding to its height above them, pushing them before it until their course is arrested by heurters, which are so placed in the drums as to stop the counter-wickets at the moment when the wickets, carried along in the movement, assume a vertical position.

"If now the up-stream valve of the pipe which has been opened be closed, and the down-stream valve which had been closed be opened, the water which had entered the drum will escape into the lower pool; the counter-wickets, relieved from pressure, will no longer be able to hold the wickets in a vertical position, and the latter, yielding to the pressure against them, will lie down on the weir.

"The maneuvers of raising and lowering the wickets are thus reduced to the simple opening and closing of two valves; moreover, as the rapidity with which the wickets move depends upon the speed with which the compartments of the drums are filled or emptied, it is easily conceivable that we may, if we so desire, so regulate it that the operation will be performed gently, without vibration and without shock. This condition is essential in order to preserve the mechanism.

"When the wickets are up, there will necessarily be more or less leakage around the edges of the counter-wickets. If this is left to accumulate in the lower compartments, they would soon be filled and the pressure on the counter-wickets would be neutralized, and the wickets would fall; but, to avoid this inconvenience, all that is necessary is to open the down-stream valve of the second pipe in the pier, which communicates with these compartments, and the leakage will flow off into the lower pool as fast as it occurs. Strictly, it would suffice to make this water pass to the ends of the compartments; but by carrying it on to the upper well, we obtain the power of acting with very great force on the wickets, that are slow to fall when the weir is to be opened; it is only necessary to close its down-stream valve and to open its up-stream one to cause the water of the upper pool to enter the lower compartment, and, by pressing the counter-wickets in reverse, to add its pressure to that which is directly on the wickets.

"Dams that permit overflow have the immense advantage of seldom requiring maneuvering, as generally they only need be lowered in heavy floods, when an overflow of the banks is threatened. However, this is not always the case, as the lowness of the banks, the neighborhood of a manufactory, or of a low bridge, &c., may cause even small fluctuations in the level of the pool to be injurious, and may make it necessary to open for rises of from one to two feet. But then a serious inconvenience presents itself, for the throwing down of the wickets along the whole length of a weir will unmask an opening greater than is necessary for the passage of a rise, and the upper pool will fall in a few minutes below its normal level. To meet these special cases, the movable apparatus has received a slight modification, of which we will now speak."

Each wicket has a prop hinged to it in rear, whose foot moves in a cast-iron slide fastened to the floor of the weir. This slide has no heurter, and is merely used as a guide. A horizontal iron bar in a suitable channel extends parallel to the wickets for the full length of the weir. This bar has a raised side, in which suitably-arranged notches are cut. If we desire to lower all the wickets, the bar is moved so that a notch comes opposite the foot of each prop, and there is then nothing to prevent the wickets from falling. If we think it desirable to partly lower some of the wickets, the bar is moved so that the raised side closes the slide of these wickets only. When the feet of the props reach this movable heurter, the movement of the wickets is stopped. As the bar is only worked when the wickets are up, there is no pressure against it, and no difficulty in setting it as may be desired. It is placed at such a distance from the wickets that when they are stopped by it they stand at half height.

Besides pipes in the pier, a similar arrangement is made in the abutment, for which the following reasons are assigned:

"In the first place, by this arrangement twice as much water can be passed into the upper compartments of the drums, and to that extent the raising and lowering of the wickets is more speedy and certain.

"Consequently the power is obtained of causing strong currents in the drums, which sweep out the sands that are deposited there. In fact, experience teaches that by the simple movement of the valves it is practicable to drop a greater or less number of wickets, and we can drop almost any desired number. In fact, it can easily be understood that if, while the wickets are up, the down-stream valve of the raising-pipe (the one corresponding to the upper compartments of the drums) be opened and the up-stream valve be closed while the opposite arrangement is made in the abutment, a current will be started in this compartment whose pressure, quite strong near the abutment, will decrease toward the pier, and near the latter will be insufficient to hold the wickets vertical. Two or three wickets will then fall. If, in this state of things, the down-stream valve of the lowering-pipe (the one corresponding to the lower compartment of the drums) be closed, and the up-stream valve be opened, a current will be established in this compartment whose counter-pressure, strong near the pier, will decrease near the abutment, and some more wickets will fall. Between these pressures and counter-pressures, or, if it is preferred, between these two opposite forces, which act at once upon all the wickets with variable intensities and in opposite directions, one of which predominates at one end of the weir, and the other at the other, there will necessarily be found along the weir a passing point where these two forces will be in equilibrium. On one side of this point all the wickets will fall; on the other side they will stay up; but as the intensity of each one of these two forces depends upon the greater or less opening of the pipes, it is possible, by suitably working the latter, to bring near or to move away the passing point, and, consequently, after a few trials, to drop any desired number of wickets."

The method of working the valves is simplified by placing the two pipes vertically over each other, and having but one valve for the upper end of each, and one for the lower end. In practice it is found that when one end of a pipe is open the same end of the other pipe is closed. Each valve is therefore arranged so as to close one pipe as it opens the other. Moreover, as the two ends of the same pipe are never both open or both shut at the same time, it is advantageous to connect the two valves by a balance-beam so that they may always work together. This arrangement is shown in Figs. 46, 47, 48, and 50.

The whole combination could be made automatic by connecting the rod of the upper valve with a float, but this has not yet been done, as the desirability of making dams automatic is yet doubtful.

The following is the method of working such a dam as has just been described:

If the dam be supposed closed, and the discharge near that of low water, it will be necessary to close the spaces between the wickets by needles in order to keep over the whole dam an overflow two inches deep, which secures the normal level of the pool. If a storm occurs, or a slight increase of discharge, these joint covers are removed; if the volume discharged continues to increase, and the overflow deepens, it can generally be permitted to do so without inconvenience, and without the need of maneuvering, until the depth is from 12 to 20 inches, the wickets of the pass being so centered as not to swing spontaneously under this depth of water. When the overflow attains a depth that ought not to be exceeded on account of the lowness of the banks, or the existence of bridges and mills above, the weir-wickets are partly lowered by making use of the notched bar; that is, the tops of the wickets are lowered about 20 inches, either throughout the whole length of the weir, or only for a certain distance, care being taken at the same time to properly proportion the opening of the valves; if this lowering of 20 inches does not suffice to pass the rise, it is first necessary to raise all the wickets, then to move the notched bar so as to leave the slides clear, and finally to open the weir for its full length. When the rise is past and the pool falls below its normal level, the weir-wickets are half raised by the aid of the notched bar; then, as the discharge diminishes, some of the half-raised wickets are wholly raised, until finally the whole weir is again closed.

When the high-water season arrives, all the weir-wickets are dropped, and the trestles of the navigable pass are laid down; the pass is then opened by dropping the wickets by means of the tripping-rod.

When the season returns, when the river no longer affords a natural depth of 5¼ feet, arrangements are made to raise the dam. To do this the trestles of the pass are first set up, and the low bridge, which carries the raising windlass, is constructed. Each trestle is supplied with a chain which is fastened to the breech of the opposite wicket; this chain is pulled by the windlass and the wicket is raised; when it ceases to ascend, that is, when the prop is in its place against its heurter, the wicket is left on the swing, and the others are raised in the same manner. When all the wickets of the pass are thus on the swing, they are righted in succession by bearing down on the breech, or by pulling on the chase with a boat-hook. When the discharge of the river is small, and there is, therefore, no fear of making too great a fall while the pass is being closed, which might make it difficult to raise the last wickets, it is unnecessary to first swing the wickets, and each one is righted as soon as its prop is in place above its heurter.

Experience has shown that the last wickets can easily be raised even when there is a fall of 3¼ feet water.

When the navigable pass is closed, the extension bents are placed on top of the trestles, and on them is constructed the service-bridge, which, as has already been stated, is 20 inches above the normal pool; lastly, the valves of the weir-pipes are worked in such a way as to raise the wickets.

It can be seen from the above that with the drum-wickets it is necessary to have the crest of the permanent weir about half-way between low-water mark and the surface of the pool, in order to provide space for the counter-wickets without going below low-water, as this would be costly, and make their maintenance more difficult. It is also essential that the permanent part of the weir should produce a head of water in order to obtain the power needed to raise the wickets.

The lifts of the eight dams on the Marne vary from 6 feet 7 inches to 8 feet 2 inches above low water, and their average lift is 7 feet 3 inches.

Raising the pass-wickets by means of a boat is not practicable on the Marne, as the greater height of the weir makes it necessary to first raise all of the pass-wickets on the swing, which method deprives the boat of any points of support, and makes the use of a service-bridge imperative. This bridge is also useful to secure communication with the pier, in which are the pipes for raising the wickets of the weir, and it also serves for the construction of a needle-dam in case of necessity.

Comparing the system adopted on the Marne with that used on the Upper Seine, M. De Lagrené comes to the following conclusion:

1. The Marne system is well adapted to high dams, but not so much so as the Seine system, (Chanoine wickets,) as it requires a greater height of weir.
2. On the Marne there is danger to the attendant in having to cross to the pier on the narrow service-bridge (2½ feet wide) at all hours and in all weathers, and it increases with the length of the bridge. A hand-rail or rope can, however, be used to diminish this danger.
3. The Marne system does not regulate automatically the level of the pool, but it is thought that the level will be sufficiently regulated by the overflow, if the wickets be hinged at a suitable height.
4. It has the same advantage as the Seine system in having the weir placed on the side farthest from the lock.
5. The Marne weirs have the great advantage of permitting the use of the notched bar for lowering the whole movable part of the weir to half height, by which arrangement we can avoid the concentrated currents that, on the Seine, rush through the openings left by such wickets as have swung of their own accord. These concentrated currents cause dangerous scours below the weir.
6. The Marne weirs can readily be repaired, as all the movable parts are above low water.
7. The Seine system offers less obstacle to the passage of floods.
8. It is also better adapted to navigation by temporary artificial floods.

9. Nearly twice as much masonry is used in the Marne weirs as in those built on the Seine, although it is thought that much of this excess might be avoided.

COMPARISON OF POIRÉE, CHANOINE, AND DESFONTAINES SYSTEMS.

In Vol. XV, 1868, *Annales des ponts et chaussées*, M. Saint-Yves, engineer *des ponts et chaussées*, discusses the subject of movable dams, and replies to the article just quoted of M. De Lagrené.

The following is the substance of his remarks:

In reference to Poirée needle-dams, he states that, at the Marlot Dam, the trestles have a height of 11 feet. The first needle-dams were accompanied by permanent weirs, raised to the level of the upper pool, and the trestles were made higher than this level, so that the surface of the pool was regulated by the weir only. As the lift of dams was increased it became impossible to use such high weirs, and at some dams they were altogether omitted, the regulation of the pool being accomplished by suitably spacing the needles.

M. Saint-Yves denies that there is any excessive labor required of the dam-tenders, for they are not picked men, and they find no difficulty in carrying along the bridge two needles at a time, each weighing from 26 to 33 pounds. He also states that the placing of the needles is neither difficult nor dangerous; that a needle seldom misses the sill, which presents a shoulder of 6 inches; and that, when it does miss, the attendant has only to lower his hand to prevent being carried overboard. The needles are always removed by hand, even when the lift reaches 10 feet. The work requires skill, but it can easily be acquired in about two weeks. The width of the foot-bridge has been increased to 3 feet, and each plank is now kept in place by three claws, which hold them perfectly steady. Maneuvers executed from a bridge are much less dangerous than those from a boat. Moreover, except in rare cases, night-work on the Lower Seine is not required. The exceptions are limited to the cases of a discharge of the pool above, and to the effect of the tides. Inconvenience on the first account is prevented by the service regulations, as no important maneuver is permitted without notice to the dam-tenders above and below. The tides only give trouble at Martoc, and this has been obviated by the addition of a weir, provided with automatic Chanoine wickets.

The partial opening of a needle-dam has never prevented a boat from entering a lock. The dams are generally placed at the lower end of the lock, and only occasionally at the middle. As the openings in a needle-dam extend to the bottom, and are evenly distributed either in one bay or in a number, and as there is never a flow over the top of such a dam, there is evidently less danger of scour below this dam than below any other. Moreover, scour is chiefly to be dreaded in times of high-water, when all dams are out of the way.

The highest trestles can easily be raised by two men with a boat-hook, and the use of chains has been abandoned, thus removing the only thing that prevented the trestles from lying flat in the recess; moreover the sill now projects 14 inches above the trestle recess, as do also the pavement below the recess and the piling, so that boats and rafts that clear them must clear the trestles. As to the charge of unhealthfulness due to stopping floating bodies, M. Saint-Yves very properly says that the charge might equally be made against any dam whatever; but that the needle-dam is the least objectionable on this score of any, as the removal of a few needles will readily pass anything through it.

He makes the following comments on dams formed by Chanoine wickets:

In raising Chanoine wickets the attendants work from a boat, and therefore are much more exposed to danger than if they were on a bridge with a floor 3 feet wide. The joint-covers that must be used during low-water cover spaces of 4 inches, and they therefore must have a cross-section at least 6 inches square. They therefore can hardly be called needles, and as the pressure on them for a length of 11½ feet is 2,020 pounds, they evidently can only be removed by means of the boat; this operation is probably safe enough at the pass, as the pass-wickets are stable, but it is very unsafe at the weir, as any pressure against the chases of the weir-wickets will swing them. The joint-covers of the weir will therefore have to be abandoned, and left to be carried off by each rise. Moreover, the effect of the joint-covers will be to make all of the weir-wickets swing at the same time; and, as this will frequently occur, the result will be that, in practice, the covers will not be replaced, and the dam will not be sufficiently tight. [It will be observed that, in the system as now employed on the Upper Seine, the weir-wickets are maneuvered from a service-bridge, and therefore the above objections no longer apply.]

M. Saint-Yves denies that floating bodies will all be drawn away from the pass to the weir, because their crests are at the same height during the greater part of the time, and there will consequently be the same flow over each, and therefore bodies will strike one as often as the other. There is also some danger that boats or rafts going through the pass, and drawing all the water, may catch on some of the Chanoine wickets, and tear them out, for they are on the same level as the sill, and are not protected like Poirée trestles. The Chanoine wickets have a multiplicity of parts, and repairs to them must be made by means of a skiff, or by employing a diver, while Poirée trestles are often replaced from the foot-bridge without any difficulty, and without using a skiff, or needing a diver.

The greatest advantage of the Chanoine system is the facility which it affords of opening gaps, so that boats may pass without going through the locks.

He thinks that, as the Desfontaines wickets require to be sunk about one and a half times as deep as the lift which they create, they can hardly be considered a system of movable dams; but, on the other hand, the results thus far obtained show that they are the best, the easiest worked, and the most reliable of all wickets designed for use on weirs. They have not yet been made automatic, although M. Desfontaines thinks that they could readily be made so by using floats. Where self-regulation is not a necessity, they appear preferable to any other combination. He does not consider the Poirée needle-dam perfect, but that it has been very successful wherever thus far used, although of late an increase of lift has been called for, and new exigencies have arisen.

The history of the construction of movable dams is as follows:

The first type of movable dam is found in the old river-gates, the elements of which consisted of two pieces placed transversely to the current, one at the bottom and one at the top; the first (the sill) stationary, the second (the boom) movable. Against these two horizontal chief members rested vertical rafters, like needles, whose feet were supported by the sill, and their tops by the boom. Lastly, boards placed horizontally completed the closing, and made it nearly water-tight. This is the river-gate, as it still exists upon a great number of streams, and we have seen many specimens of it, especially on the Eure.

This primitive construction only partly satisfied the needs for which it was established, and besides it is only practicable on very narrow streams. The opening of these gates requires long and painful labor. They are not admissible upon rivers of any width, where the rises are at all rapid, and M. Poirée had to discuss an entirely novel question when he was seeking after his system of dams.

Every movable dam ought to form a connected body of supports, designed to sustain a curtain, which at will can be made as tight as possible, and which is placed at right angles to the current. How, then, ought the members to be arranged which hold up this curtain ?

The first necessity was to suppress the upper support of the river-gate, so as to shut off by a single gate the whole width of the water-course, and to establish axes of rotation fastened to the bottom of the river.

The most natural and logical idea was evidently to profile these members in the direction of the current, and to give the same direction to the axes of rotation. Under these circumstances the lowering and raising of the members could be only moderately hindered by the action of the current.

With the opposite arrangement, that is, when the axes of rotation are established at right angles to the current, if the lowering is helped, and possibly even precipitated by the pressure of the water, the raising becomes that much more difficult, and demands maneuvers which can only be accomplished by the aid of special machinery. Thus we see that the invention of M. Chanoine is but an extension, a perfecting, of the invention of M. Thénard, which latter was only designed to be placed on top of weirs: that is, to act under circumstances where the pressureof the water is feeble and sometimes null.

Under this view the invention of M. Poirée should be considered as the most logical

The movable trestles of M. Poirée, whose part, as we have said, is to act as frames for supporting a curtain, which in reality forms the dam, are not only very logically and very rationally conceived, but, in addition, they have the immense advantage of being a natural support for the bridge, which latter may be called the working-ground for the dams. In every system whose axes of rotation are at right angles to the current, even in the ingenious system of M. Desfontaines, the possibility of making a foot-bridge out of the necessary members of the system is entirely lacking; it is necessary to employ for this purpose an independent construction.

We finally come to the part of the dam which must resist the force which is to be overcome, the maneuvering of which brings about a direct conflict with the force of the water. To obtain an easy and practical solution of this question, M. Poirée reduced his tools to the smallest possible dimensions, and from this consideration came the invention of needles. The pressure in maneuvering is in direct ratio to the surface of each one of the elements. It is, then, only in accordance with the enlightened judgment and perspicacity which characterize M. Poirée's system that the dimensions of the needles, the elements of the great curtain of the dam, were reduced as much as possible.

The other systems have been conceived on the idea of substituting for the needles elements individually very small, and consequently very numerous, a complete apparatus of shutters, which are much more complex, but are also fewer in number. The employment of axes of rotation at right angles to the current is a necessary consequence, that could not have been avoided.

The raising of the shutters, which takes place against the current, presented a very serious difficulty. It has been very skillfully overcome in the plan of M. Chanoine by the use of two parallel axes of rotation placed at different heights. This arrangement permits the wicket to be kept practically parallel to the direction of the threads of water while the support is being raised. Theoretically the water-pressure is only exerted upon the edge of the wicket and upon the members of the support. Practically this is not exactly the case, and the exertion to be made exceeds the quantity of work that could be required of two or three men unsupplied with mechanism. Special apparatus must therefore be used.

M. Desfontaines's solution, which likewise employs a system of axes turning at right angles to the current, is certainly very ingenious and very satisfactory. The method of raising M. Desfontaines' wickets is simple, and but one motion is necessary, while to lift the Chanoine wickets two operations must be performed and two motions are required. The Desfontaines wicket rises directly against the current, without the aid of any detached or outside machinery. The force utilized is not that of man, increased by mechanical intermediaries. It is the very force to be overcome that assists the engineer, and, blindly obeying the intelligent direction which is impressed on it, contends against itself, and, from the enemy which it seems to be, becomes a docile instrument.

This remarkable result is obtained by the simplest means. Undoubtedly the iron frames of M. Poirée, with their curtain of needles, offer the greatest simplicity in construction. But the system of M. Desfontaines, several examples of which may be found on the Marne, is reduced to a movement of valves, connected together by a balance-beam, which work under a simple and easy impulse, and to wickets in one piece, which turn around a horizontal axle, without the complication of counterpoise, retaining-chains, props, or tripping-rods. In view of its unity and of the simplicity of its conception and its working, it is one of the most remarkable inventions that ever originated from the laborious investigations of engineers.

But, in consideration of the necessity of a carefully-constructed inclosure, this system, for the present at least, ought to be restricted to use on weirs.

Besides the considerations just mentioned, it is of the greatest importance that a dam should be susceptible of being made water-tight, should necessity demand it. In this respect he thinks that there is a great deal yet to be done. The difficulty arises from the fact that the fall at a dam reaches its maximum when the river has its minimum discharge, and that at this time the water passes through the intervals with the greatest velocity, and more may thus be wasted than can be supplied from above, thus causing a decline in the level of the pool. At the same time, owing to the absence of back-water, the pressure on the needles is greatest, and they are often broken during the maneuvers necessitated by rises.

The following are M. Saint-Yves' conclusions as to the system that should be used in various cases:

If the river in question can only be navigated by artificial waves, in which case it is necessary to pour out in a short time the whole retained body of water in order to send forward a large volume, capable of increasing the navigable depth temporarily, but very appreciably, we think that it would be better to use Chanoine wickets, which seem preferable to the needle-dams with escapements, which are used on the Yonne. The advantage to navigation appears to us to exceed the inconveniences which we have pointed out, and which result from a relative imperfection, which subsequent studies may cause to disappear.

If the river in question has a regular regimen, with a discharge sufficient to assure, by means of pools suitably spaced, the draught necessary for a good navigation, we would not hesitate to choose Poirée dams, on account of their safety and facility of handling, and the means of communication which they give from one bank to the other for the superintendents and for those who have the care and working of the dams.

In regard to wiers, a distinction must be made. Either self-regulation is indispensable, or it is only an advantage. If it is indispensable, we think that it is only so in order to secure an additional and supplementary opening to the waters which threaten to submerge the works, and not at all in order that this opening may be closed instantaneously. On this supposition the wickets of M. Chanoine are the best adapted; but we think it important to make a reservation, that is, that the swinging should not be limited to a slight lowering below the level of the pool, which makes it necessary to have an expensive and sometimes impracticable lengthening of the weir, but that the swing should be increased as much as possible by entirely taking away the power of spontaneous rising. In a word, the wickets of the wier should be considered as semi-automatic. A foot-bridge established above the wickets will permit the dam-tender to raise them mechanically. We think that in this way alone is it possible to give a sufficient discharge over a limited length of weir.

If self-regulation is not necessary, M. Desfontaines' system appears to us preferable for crowning weirs. In fact, the simplicity of the wickets, the ease with which they are worked, and the exact control of their fall, are precious qualities, by which results as powerful as they are sure can be obtained when the weir is not too long.

In conclusion, we think that the comparison between different kinds of dams should be limited to the Poirée and the Chanoine, and that the Desfontaines wickets, thus far only applicable to weirs, should be considered as auxiliaries, but not as a system.

REPLY OF M. DE LEGRENÉ.

In tome XVI, 1868, Annales des Ponts et Chaussées, M. de Lagrené replies to M. Saint-Yves, and the following is a brief summary of his remarks.

He begins by quoting, in reply to the latter's assertion that needle-dams are not dangerous, a statement of M. Cambuzat, who says:

With needle-dams there is really considerable danger to men who open them in rainy and frosty weather and during floods, or at night, *while in working wicket-dams there is no danger at all to the attendants.*

He adds:

That in 1859 a lock-tender was drowned at the Epineau Dam while opening it on the arrival of a small rise, and that very often the attendants fall into the water during the opening of needle-dams.

The danger seems to be much greater on the Yonne, where navigation is intermittent, than on the Lower Seine, where night-work is never necessary. On the Belgian part of the Meuse, as on the Yonne, the attendants often fall into the river, and in 1866 two of them were drowned at the Haignaux Dam.

It seems to me that in every case where the discharge of the stream in question varies rapidly, or where there is navigation by artificial waves, the preference, if only on the score of humanity, ought not to be given to needle-dams, unless the methods of working them are changed, which is probably quite practicable.

M. Cambuzat recounts several instances of trouble with wicket-dams, such as tripping-rods and horses broken, wickets remaining up, scour at the foot of the passes.

Injuries to some of the parts appear to me to be accidents which prove nothing against the system; in fact, I can cite the Melun Dam, whose navigable pass is furnished with fifty wickets, which were maneuvered during all the artificial floods of 1865, that is about fifty times, without a single wicket ever refusing to fall, and without any damage whatever being reported. He acknowledges, however, that the construction of a Chanoine wicket-dam demands very great care in the exact location of all the parts, and that the attendant must also be very watchful, when raising the wickets, to see that no foreign matter interposes between the heurter and the foot of the prop, otherwise the tripping-rod might not act on it.

The weir that regulates the level of a pool is the most important part of a movable dam; it ought, if possible, to give passage for an overflow of such length that its depth shall in some measure suffice for regulating the level of the pool without any intervention of the lock-tender. If, in consequence of an increase in the discharge, the overflow no longer suffices to pass a rise, the weir ought by spontaneous movement to give an increase of discharge corresponding to the supply; that is, it should increase or decrease with the latter. Finally, it is desirable that the lock-tender should be able whenever it is necessary to control these spontaneous movements, and at any instant to have perfect command over the apparatus for closing.

If a weir is so arranged as to fulfill the above requisites, it seems a matter of indifference how the object is accomplished, as where there is a continuous navigation the pass is but seldom maneuvered. The system that uses a needle-dam on the weir, and wickets in the pass, seems objectionable, as it does away with a regulating overflow where it is needed, and places it where it may be injurious.

The article concludes with a description of the Suresnes dam, with which the author is very familiar.

The navigable pass of this dam, or rather the pass adjoining the Suresnes lock, is closed by needles; the trestles, sixty-five in number, are 11 feet in height and are spaced at intervals of 3 feet 7 inches. The dam was first closed on the 2d of June, 1867, and since then the fall at this dam, which varies according to circumstances, has never exceeded 7 feet. The number of needles in use or in store on the 2d of June was nine hundred. Between the 2d of June and the 22d of October, 1867, that is less than five months, five hundred of these needles were broken. Leaving out of consideration two hundred which were broken by being struck by a boat, there still remain three hundred cases of rupture, which occurred while placing or removing the needles, and sometimes while they were under pressure, without any apparent reason. These needles were 13 feet long, with a cross-section of 3 inches by 3 inches.

While waiting for another supply of needles of northern pine, with a section of 3¼ by 2¾ inches, pine scantling, 9 inches wide and 2¾ thick, were used in place of needles, and they are still in use, although some of them (about ten) are already broken. They were placed in very much the same way as the ordinary needles; the height at which one of them ought to rest against the supporting bar when in position was known beforehand; the scantling was then placed nearly horizontal, resting on the bar at the proper mark, and then the up-stream end was slightly lowered; the current immediately carried this end under, and righted the scantling; the head was held back in order to lessen as much as possible the shock against the sill. To withdraw a scantling, use was made of a boat with a windlass; this boat was suitably fastened to a mooring-cable stretched across the upper end of the pass; each scantling was drawn out head foremost by means of the windlass, and taken on the boat.

This method of removing the needles of the Suresnes dam is a necessity whenever the fall is as much as 6¼ or 6½ feet. Information obtained from the attendants at other dams is to the effect that needles are only put in place or removed from navigable passes when the fall is reduced to 5 or 5¼ feet.

MOVABLE DAMS ON UPPER SEINE.

In the same volume of the Annals, MM. Chanoine and Lagrené give an elaborate description of the twelve dams constructed on the Seine between Montereau and Paris, with full details of the methods used in constructing the foundations, and of all items of cost. This will be given at sufficient length for the purposes of the present report from the later report of M. Cambuzat, but reference is made to it for the benefit of those who may desire to go more fully into this subject. The following items are, however, quoted here, as they are not referred to by M. Cambuzat.

Careful observations on the river, before and after the construction of the dams, showed that they produced no sensible effect on the heights of floods. When they are submerged a very slight ripple on the surface is all that can indicate their presence. The works themselves were not injured, especially if the lock-gates were opened before the arrival of the flood. The only effect was a slight deposit of sediment in the locks.

The time allowed for passing a fleet of eight boats through a lock is twenty minutes, half of which is used in filling or emptying the lock, and the other half is needed for getting the boats in and out, and for closing and opening the gates. The use of a submerged chain for towing has increased this time to twenty-eight minutes. A single tow-boat can be passed through in fifteen minutes. The larger the lock the better, when navigation is habitually carried on by fleets, as there is a very great gain in being able to pass a whole fleet through in one lockage.

The average time necessary for raising such wickets as are used on the Upper Seine is two minutes and ten seconds for each wicket.

In dropping a number of wickets there is sometimes considerable difficulty in moving the last ones, on account of the pressure on the tripping-rod of those first dropped. This is remedied by passing an iron band under the caps of the axle of the wicket, so that when the wicket is down it is raised a little higher above the tripping-rod, and there is less danger of the weight of water pressing it against the rod.

As it is important that the lock-tender should have some index to show him, at all times, the number of the wicket on which the tripping-rod is acting at the moment, several have been invented, three of which are described. They are geared so as to move either with the tripping-rod or with the axle of the pinion that works it.

Should a wicket remain standing after the others have fallen, the lock-tender, after the current through the pass has somewhat lessened, approaches it from below in a skiff, and drops it by a side-blow on the prop.

If it becomes necessary to swing the weir-wickets at a time when the overflow is nearly sufficient to swing them of itself, it is unsafe to use the service-boat, unless it is fastened to a line of piles above the weir, as any pressure against the wickets, even though the boat has long fenders, might swing them.

A full discussion is given of a modification in the manner of connecting the weir-wickets with their horses, so that after these wickets swing, the level of the pool may be kept constant as the discharge increases. This change, however, seems not to have been adopted in practice, and therefore need not be considered here.

JOINVILLE DAM ON THE MARNE.

In the same volume of the Annals is an article by M. Malézieux, engineer of *ponts et chaussées*, on the Joinville dam, from which the following is taken. Joinville is about 11½ miles above the fortifications of Paris, measured by the river, and about 4½ measured by the St. Maur Canal.

A dam had been in existence on the Marne at Joinville for forty years. It was constructed in order to raise the water to a minimum depth of 5 feet in the St. Maur Canal, and at the same time to create a fall, which caused the construction of important manufactories along the banks of this canal. The necessities of navigation having been greatly changed, the first thought was to raise the old dam 2 feet, which would be enough to give 5¼ feet of draught in the river between the upper end of the St. Maur Canal and the lower end of the Chelles Canal. But the city of Paris became, in 1864, the owner of the manufactories of St. Maur; and from that time the motive power was used to pump up the Marne water, in order to supply the Vincennes lakes and the elevated parts of the capital. The city requested that the Joinville dam should be raised 3¼ feet, and offered to share in the cost. This was about the highest elevation that could be permitted without serious inconvenience, if not on account of the submersion of the banks above, at least on account of the heights of the cargoes of the charcoal-boats which pass through the tunnel of the St. Maur Canal. The proposals of the city were accepted by the state.

It was found inadvisable to rebuild the old dam, and an entirely new one was built about 1,400 feet below the old dam, so as to leave a basin of a little more than 12 acres below the mouth of the St. Maur Canal. This canal is a cut-off by which boats pass through two-thirds of a mile of canal instead of eight miles of river. As navigation goes almost entirely through the canal, there is little need of a navigable pass, and accordingly it is only 39 feet wide. The weir is 207 feet in length. The wickets are 3 feet 7 inches high, and their tops are 8 feet 2 inches above the bottom of the St. Maur Canal. The lift of the dam in low-water is 7 feet.

Experience on the upper dams of the Marne having shown that the Chanoine wickets were liable to many accidents, and the Marne not being a river subject to sudden heavy floods, and there being, on account of the special peculiarities of the situation, but seldom occasion for opening the pass of this dam, it was thought best to close the latter by a needle-dam, and to use the Desfontaines wickets on the weir.

The Desfontaines system has been in operation at the Damery dam since 1857, and at the Courcelles dam since 1861, but is still not well known, and M. Malézieux gives a description of it, from which we only extract such matter as has not been mentioned already.

The weir is contained between two rows of sheet-piling, 26 feet apart. The up-stream capping-pieces are even with the permanent sill, at 3 feet 8 inches below the level of the pool; the down-stream caps are at the level of low-water. Before the piles were driven, the area to be covered with beton was dredged. The least thickness of beton below the level of the low-water below the dam was taken at 4 feet, but this depth was occasionally exceeded.

The first thing is to construct the main body of masonry, which contains a cavity 7 feet wide, with a cross-section composed of a quadrant adjoining a rectangle, and extending from one end of the weir to the other. The two edges of the opening have cut-stone borders. When this is finished it is divided into sections, or drums, each 5 feet long, separated by large transverse diaphragms of cast iron. These plates enter the masonry to a depth of 3 inches, and each one has two openings cut through it; one is on the up-stream side near the top of the quadrant, and is wider than it is high, making a horizontal opening the other is on the down-stream side, is higher than it is wide, and forms a vertical opening. The latter is made of such a size that a man can without much difficulty pass through it from one end of the weir to the other.

Each drum now received a large plate-iron wicket, which has near the middle a horizontal hinge. This hinge is a cast-iron tube, which contains a wrought-iron spindle from one end to the other. Its extremities rest on the two diaphragms, at the level of the upper border but nearer the lower. The wicket itself is formed of three arms, each 7 feet 11 inches long, and of two pieces of sheet-iron two-tenths of an inch in thickness.

The arms pass through the hinge, and inside of it are shaped as collars, in which the axis turns; they completely fill the annular space between the latter and the inside surface of the hinge.

The counter-wicket, starting from the hinge, is bent backward 1 foot 4 inches, and then becomes parallel to the wicket. The object of this is to prevent the counter-wicket from extending above the horizontal opening when the wicket is down. When the wicket is up the down-stream side of the counter-wicket coincides with the up-stream side of the vertical opening. It is prevented from passing this position by a wooden sill, against which its lower edge rests, by two moldings on the diaphragms that correspond in shape to the sides of the counter-wickets, and by a molding on the hinge which comes in contact with its upper edge. There is a play not exceeding one-seventh of an inch between the counter-wicket and the walls of its drum. To secure such accuracy of fitting the iron-work is planed, and the stone-work of the cylinder is covered with Portland cement, which is accurately shaped by a cutting-tool turning on the axis of the wicket. When the wicket is up the counter-wicket is in contact on all sides with the projections, and as its surfaces of contact are faced with India rubber, there is no leakage. When the counter-wicket is in any other position there is a slight waste of water.

Each drum is divided by the counter-wicket into two compartments, and the top of each is covered by a sheet of plate-iron, which is fastened to the sole, to the diaphragms, and to the hinge; this combination supports the hinge itself.

The abutment, which is 9 feet 10 inches thick and 25 feet long, is pierced through the middle by a longitudinal culvert whose sections vary as follows: At each extremity are two parts, each 4 feet 3 inches in length and 3 feet 3 inches wide by 4 feet 3 inches high, into which a man can easily enter; the up-stream culvert has its sole 1 foot 3 inches above the low-water line below the dam, while the down-stream one has its sole exactly at this level. In the middle, with a length of 9 feet 10 inches, and separated from the end parts by two chimneys or wells, which establish a communication with the top of the abutment, is the essential part of the arrangement, that in which the distribution of water is effected and on which depends the maneuvering of the weir. In this central part the culvert is divided into two rectangular conduits, one above the other, and only separated by a five-eighths plate of cast iron; these conduits are each 2 feet 7 inches wide and 2 feet high. An ordinary cast-iron valve placed at the upper end shuts one of these openings while unmasking the other; there is a similar valve at the lower end. A balance-beam, to which are attached the rods of both valves, communicates to the down-stream valve the movement caused in the up-stream one, or, more accurately, the opposite movement.

In the body of masonry which separates these conduits from the outer wall of the abutment, and consequently from the first drum of the weir, two other conduits are constructed, but no longer superposed. One of them, which is placed on the up-stream side and at the higher elevation, prolongs the horizontal opening of the diaphragms until a connection is made with the upper conduit in the abutment; the other prolongs the vertical opening to a connection with the lower conduit (See the plates.)

The method of raising and lowering the wickets has already been explained.

It is essential to the successful use of drum-wickets that there should be a fall at the dam, and this is obtained by raising the permanent part of the weir. The obstacles to raising are the current and a deficiency of fall, both of which are least in low-water and greatest in high. The friction of the arms on the axis must also be overcome. It is not likely that the axes of the wickets will get untrue, as they are short and are held by three pairs of collars. The resistance of the water in the upper compartments when the wickets are lowered prevents them from coming down with a shock.

At Joinville, when the river below the dam is at low-water mark, (zero of the water-gauges,) a fall of 4 to 6 inches is sufficient to raise the wickets. If the pass is completely shut, which forces the water to flow over the permanent part of the weir, it takes about two minutes to raise the wickets and one minute to lower them. On the 5th of March, 1868, the water-surface standing at 7 feet above the dam and at 4 feet 7 inches below it, twelve minutes were required to raise the wickets, and five to lower them. On another occasion, when the water above stood at 6 feet 7 inches, and at 5 feet below, a half hour was required to raise the wickets. This is about the limit at which the Joinville wickets will work. To extend this limit would be easy, but there would be no practical advantage in so doing, and it would be a useless increase of cost, for when the water-surface stands at a height of 4 feet 7 inches below the dam, the wickets have no service to render to navigation, and the necessities that are ordinarily served by the Saint Maur pumps are more than satisfied.

It was naturally to be expected that there might be trouble at Joinville on account of the sediment and gravel that would be deposited in the drums. Experience, however, has shown that the strong currents that can be sent through the upper and lower compartments by suitably working the valves in the pier and in the abutment are sufficient to remove such deposits entirely. Care is taken to have gratings at the heads of the culverts, in order to keep out leaves, sticks, &c., and there are special valves that can be used to cut off all communication between the culverts and the upper pool during the winter season when the water is muddiest.

One great merit of Desfontaines' wickets is that they are more nearly water-tight than any others. The interval of four-tenths of an inch between the wickets can easily be reduced to two-tenths or less.

If a boat should be driven by the current against one of the wickets, and should injure it, it can at once be replaced from the spare wickets which are always in store. Such an accident could hardly happen except when the river was tolerably high, and as the upper compartments are always in communication with the upper pool when the wickets are up, in most cases the only result will be that the counter-wicket will drive back the water that presses against it, and the wicket will gradually yield to the shock and lie down.

The drums can be laid dry for repairs whenever the water below the dam does not stand higher than 3 feet on the gauge, (which is the case during half the year,) by building little dams in the piers and in the abutment, for which recesses are left. This, however, necessitates that 3 feet 7 inches be drawn off from the pool. At Joinville this plan was considered objectionable, and instead of it a line of triangular frames, 3 feet 7 inches high and 9 feet 10 inches apart, was placed on the weir above the wickets. These frames lie down like the trestles of a Poirée dam. They are used as the supports of a temporary dam of timbers 8½ inches by 4 in section, which have claws that connect them with the uprights of the frames. They are easily placed from a skiff, and the dam is made water-tight by a covering of tarred canvas, held down by weights. After the top of the weir is exposed, a little traveling-crane, running on rails and movable from one end of the weir to the other, is used for handling the wickets. In less than a day the covers can be taken off, the wickets can be raised and examined, and all can be replaced. No pump is used unless it is thought advisable to empty the drums.

Special precautions were taken to prevent wash below the weir of the Joinville dam, as the use of a notched bar to permit the half-lowering of wickets was, for simplifiation, rejected. The greatest difficulty was encountered below the pass. The following is a description of this danger, and of the means taken to meet it:

> The lower end of the sole of the pass is exposed to still more dangerous corrosions, and it may chance that the whole Marne will pass through this narrow opening of only 89 feet. In fact a scour, to the depth of 13 feet below low-water, was very soon formed at a distance of 100 feet below the pass. In order to keep the ultimate scour at a suitable distance from the dam, bearing in mind the difficulty of making the necessary repairs to a covering 2 feet 4 inches below low-water, the rock-work for a distance of 50 feet was covered, not by a masonry pavement, but by a strong flooring of oak timbers, bolted carefully to the caps that connected the six rows of piles.

The trestles of the pass are 9 feet 10 inches high and the one nearest to the pier is 6 feet 7 inches distant from it, so that a space has to be made for it in the pier, and this recess is separated from the culvert by a special casting. The service-bridge is 6 feet 7 inches below the top of the pier, and the latter is reached by a short ladder and four steps in the pier itself. A supplementary bridge is provided, whose floor is 4 feet higher than that of the main bridge, but it is seldom used, as the latter answers for most purposes.

The iron-work of the wickets cost 49,844 francs, or $9,470.

The counter-wickets of the Marne weirs are generally of the same length as the wickets, but at the Courcelles Dam the former are 4⅜ inches longer, and these wickets are in consequence perceptibly more readily maneuvered than any others. The longer the counter-wickets the greater the height of the river at which the raising of the wickets becomes impracticable.

To satisfy the local wants of the Marne navigation, M. Desfontaines adopted the following rules:

1. To make the height of the permanent part of the weir equal to half the difference of level in low-water. 2. To limit the sinking of the drums below the low-water line, at the foot of the dam, to from 12 to 16 inches. But these rules were neither general nor absolute.

There are some advantages in a high weir, provided it is not too costly on account of its length; such as greater security than a movable curtain, greater ease of establishing, examining, and repairing its movable parts, and less exposure of the latter to being covered by sand or sediment.

Besides this, the height secures the initial fall, which is necessary for the maneuvering of the wickets.

M. Malézieux believes that there is no practical difficulty in the way of making deeper drums and higher wickets on the Desfontaines system.

IMPROVEMENTS ON POIRÉE NEEDLE-DAMS.

In Vol. XX, *Annales des ponts et chaussées*, 1870, M. Saint Yves takes up the subject of the improvements practicable on Poirée needle-dams. The substance of his remarks is as follows:

One of the troubles with a needle-dam, especially when high, is its lack of tightness. After a careful investigation, which is given in full in the original, he recommended that the cross-section of the needles should be a semi-regular hexagon, obtained by taking an equilateral triangle with sides of 5½ inches, and cutting off from each of its three angles smaller equilateral triangles with sides of 1½ inches. (See Fig. 53.)

On the Seine, below Paris, the dams are 9 feet 10 inches in height, and the depth provided for navigation is 6 feet 7 inches, the crowns of the masonry of the dams being placed at a low-water line. Whenever the river surface below a dam stands at 2 feet below its top, or at 7 feet 10 inches above the masonry, the movable part is thrown down, and boats can easily cross without striking the sill. In order to prevent the boats from being entirely stopped during low-water, in case of accident to the lock, each dam has a navigation-pass closed by a needle-dam. As the needles for these passes would have to be so long and heavy that they could not be handled without great labor, it was decided by the General Council of *Ponts et Chaussées* that a movable sill should be used which could be removed whenever necessary. M. Saint Yves does not approve of this arrangement, as he thinks that in course of time the movable sill would either be destroyed, or so consolidated with the masonry that it could only be removed by tearing it to pieces.

In order to remove this difficulty, M. Marini tried, at the Bezons dam, intermediate supports for long needles, (Figs. 54, 55, 56, 57, and 58,) so that they might have three points of support instead of two. A careful examination into this question shows that for heights of 12½ feet, where the needles rest against intermediate horizontal beams, supported against the trestles at a height of 4 feet 7 inches above the sill, they resist well; and this is also the case when the height is 13 feet and the intermediate support is at an elevation of 4 feet 10 inches. With such an arrangement movable sills are no longer necessary, but more skill is required in removing needles thus supported in order to avoid being drawn into the water. The best place for the intermediate beam is a little above the center of pressure of the water. It must be observed, however, that this additional security is only obtained while the needles are in place. They are still weak to resist the forces acting on them when they are being lifted. The best remedy for the difficulty seems to be to have a special apparatus for regulating the level of the pool, so that the needles need only be lifted when the latter ceases to suffice for the discharge, by which time the lower pool will have been raised, and the pressure on the needles will thus have been diminished.

The apparatus recommended is Chanoine wickets on the weirs, but automatic action does not seem desirable, as by dispensing with it a greater swing of the wickets may be obtained. If only a short length of weir be available, Desfontaines wickets should be used, as these can lie down flat, and thus permit a greater discharge.

DAMS ON THE MEUSE.—TRESTLES WITH ESCAPEMENTS.

The arrangements on the Meuse, to open needle-dams by escapements, differ from those on the Yonne. On the latter they were designed with a view to making artificial floods, and therefore rapidity of action was specially desired. As soon as one bay was opened all the others followed, and the movement took place so rapidly that sometimes the dam-tender could not get off the bridge in time, but was precipitated into the river.

The Belgian dams, with escapements, are constructed in accordance with an entirely different order of ideas. Each escapement is put in motion by the application of an exterior force, and the openings take place singly and one after the other. The object which the Belgian engineers proposed to themselves was to avoid the removal of the needles by hand and one at a time; and by their system they have succeeded in making daily use of needles which square from 4 to 4½ inches. The handling of these little pine joists is limited to carrying them on the dam and placing them in the water, which are easy operations that require no manual dexterity, but only the effort necessary to lift a weight and carry it on the shoulder.

By using these heavy needles the height of dams can be increased to 13 feet without using intermediate supports.

GENERAL DESCRIPTION OF TRESTLES WITH ESCAPEMENTS, AS USED ON THE BELGIAN MEUSE.

Their general shape is about the same as that of the trestles used in France. They only differ in the upper part. The cap, which forms the smaller base of the quadrilateral, is surmounted by a rectangular frame-work, which carries the escapement apparatus and the foot-bridge. (See Figs. 59, 60, and 61.)

Of the two vertical parts of this frame, one, that on the up-stream side, is composed of a piece of wrought iron, which is welded to the trestle, and is afterward bored out so as to form a tube, in which turns a vertical iron rod, A. (Fig. 59.)

The clamp-bar, which connects one trestle with the next, is provided at one end with a collar which envelopes the tube, around which the clamp-bar turns. This collar is hollowed out on the larger part of its circumference so as to admit, in all its positions, (it can only describe a quadrant,) the head of the adjoining clamp-bar, B. The collar is held, so as to prevent any vertical movement, by a ring, C, which is fastened to the tube by two screws. The head of each clamp-bar is forged in the shape of a T, and enters the cavities cut out of the collar of the adjoining clamp-bar, those cut out of the tube, and lastly those cut out of the iron rod. Finally, on the under side of each clamp-bar and near its head is a vertical projection, D, (Fig. 60,) which, after the bar is turned, strikes against the cap of the trestle proper and limits its movement of rotation.

The iron rod is prevented from moving vertically by a screw, E, (Fig. 59,) which accompanies it in its quarter of a revolution, moving in a groove cut out of the tube.

The down-stream post of the top frame is arranged so as to receive a horizontal bar for supporting the iron plate, which serves to make a foot-bridge, and to bind together the trestles by means of claws. This bar has a socket on its up-stream side, which surrounds the tube.

The iron rod works in the tube by friction, and it is turned by nippers shaped like a wrench. The escapement cannot, therefore, act spontaneously.

The dams on the Meuse are divided into two passes by a pier, which is hollowed out so as to have chambers on each side to receive the end trestles. There are no niches in the abutments, and the trestles are always dropped in the same direction.

The trestles are connected by chains, but the necessity of leaving room for the clamp-bars to turn and the needles to escape compels the division of the chains into two parts, one of which is fastened to a trestle, and the other to the flooring of the adjoining trestle. When the trestles are lowered these chains are connected, but they are separated when the bridge is up.

The trestles are bedded by giving them a slight push after raising the floor, so as to disengage the claws. They are raised by using a light portable windlass. The needles of each bay are connected by a rope which passes under the flooring, and is fastened to the down-stream post of the trestle. When it is necessary to increase the discharge, a certain number of bays are opened by turning their clamp-bars. In this case the end of the rope which holds the needles of each bay is tied to a cable which is fastened to the pier or abutment, so that the needles float to them and are picked up at leisure.

From the above the author concludes that it is quite practicable to use the Poirée system, with a regulating weir provided with Chanoine wickets up to a height of 13 feet; but the semi-regular hexagonal needles should be preferred in order to prevent excessive leakage.

The best exemplification of the present practice of foreign engineers in improving a river on a plan similar to that proposed for the Ohio is to be found in the works recently executed by the French government in the Upper Seine and Yonne.

IMPROVEMENT OF THE YONNE AND THE UPPER SEINE.

The following description is taken from the March number for 1873, of the *Annales des ponts et chaussées*. This article is so valuable in itself, and so pertinent to our present investigation, that but little of it can be omitted. Unfortunately the illustrative plates do not accompany the text, but are promised in some future number. It is believed, however, that the plates that accompany the other reports sufficiently explain this one. The author is M. Cambuzat, chief engineer *des ponts et chaussées*.

> The great water route connecting Havre, Rouen, and Paris with Lyons and Marseilles, by the Seine and Yonne Rivers, the Burgundy Canal, and the rivers Saône and Rhone, (see map on plate 6,) had, until September, 1871, a very defective section; in fact, a veritable gap, 118 miles long, between Paris and Laroche, where the Burgundy Canal enters the Yonne. In fact, for eight or nine months of the year, from March to November, the descent of loaded boats was only possible, especially on the Yonne, twice a week, by the aid of artificial floods or waves from the Upper Yonne, and the draught of water available varied from 2¼ feet to 3 feet 4 inches, and 3 feet 7 inches at most; so that boats from the Burgundy Canal, drawing from 3 feet 7 inches to 4 feet 7 inches, were obliged to break bulk at Laroche. As to ascending craft, they were generally empty, or only carried a few tons of merchandise. This costly, slow, and altogether insufficient navigation, was accompanied by great fatigue, by danger, and by numerous accidents. Although it was somewhat less difficult on the Seine, navigation was much hindered, and often stopped, between Montereau and Paris. Since the 1st of September, 1871, there has been a continuous navigation between Paris and Laroche, thanks to 17 movable dams constructed on the Yonne, and to 2 cut-offs and 12 movable dams constructed on the Seine. The minimum depth of water in the pools is 5 feet 3 inches, and therefore boats can move up and down with perfect safety, drawing from 4 to 5 feet. At present, while the works are yet incomplete, the greater part of the loads, especially those that come from the Nivernais Canal, do not draw over 4 feet; but when the works of the same kind (that is, 8 movable dams and one cut-off, now being built between Laroche and Auxerre, where the Nivernais Canal enters) are finished, which will be by the end of this year, (1873,) the great advantages will be happily realized which the government had in view, and which were looked for with impatience, but with confidence, by the boating, commercial, industrial, and agricultural interests.

The greatest flood ever known on the Yonne, that of January, 1802, rose 16 feet at Montereau. The low-water discharge between Auxerre and Laroche is 459 cubic feet per second, and the average slope 3½ feet per mile; between Laroche and Montereau the discharge is 600 cubic feet per second, and the slope 1 foot 10 inches per mile.

The first effort to improve the navigation of the Yonne was directed toward checking the flow of the artificial floods by movable dams, in order to prevent their too speedy absorption. On this plan, descending boats and rafts were stopped at each dam, and after all had arrived a new flood carried them to the next one. But the increasing demands of commerce for a *continuous* navigation caused the adoption of the present system. Between Laroche and Montereau (the mouth of the Yonne) there are now 17 movable dams, of which 6 belonged to the old system of navigation by temporary floods. These had each a navigable pass varying in width from 194 to 230 feet. One of these dams was replaced by a new one, but the others were retained, with some modifications. Each had a lock attached for use during low-water. Eleven new dams were constructed, all of which have locks attached, except those at the heads of cut-offs, whose locks are generally at the lower end of the cut-off. The navigation passes of these new dams are 115 feet in width, and the weir has a minimum length of 164 feet. The sill of the navigation pass is placed at 2 feet below the low-water line. The sill of the weir is placed 20 inches above the same line, and therefore is 3 feet 8 inches higher than the sill of the pass. Two cut-offs across difficult bends shorten the river a little more than 4 miles. At the head of each cut-off is a guard-lock and at the lower end a lift-lock. At the Courlon cut-off the lift of the lower lock is 12 feet 9 inches. The bottom width of each cut-off is 52½ feet.

Wherever dredging was necessary a channel was made 100 feet wide and 5 feet deep at low water.

The works for improving the navigation between Montereau and Laroche, authorized in 1861, were nearly completed in 1868, when a continuation up the Yonne to Auxerre was ordered. These new works were commenced in 1869, and although rétarded by the war with Germany, will probably be completed by the end of the present year. These new works consist of eight movable dams, (of which seven have locks,) one cut-off, dredging, bank-protection, and minor works. The dam of La Chaînette, just below Auxerre, has a navigation-pass 138 feet wide, closed by a Poirée needle-dam, and a permanent weir 656 feet long, whose top is even with the surface of the pool. The sole of the navigation-pass is 20 inches below low water. The chamber of the lock attached to the dam is 27 feet wide, and has an available length of 305 feet. This dam was built under the old system of creating temporary floods. The seven new dams have navigation-passes varying in width from 98 to 115 feet, closed by Chanoine wickets, with their soles 2 feet below low water. The weirs, whose soles are 20 inches above low water, are from 82 to 131 feet in length. Six of these weirs have needle-dams on the Poirée system, and one has large Girard shutters 11½ feet wide, with a vertical height of 6½ feet.

Five principal conditions controlled the decision on the position and lift of each dam:

1. The preservation of existing dams.
2. The horizontal plane passing through the tops of the wickets of the navigation-pass (whose height fixed the lift of the dam) should be 5 feet above the lower miter-sill of the lock next above, and the same distance above the intermediate bars, excepting those which were to be dredged.
3. The height of the natural banks should be at least from 16 to 20 inches above the level of the pool, excepting that certain parts near the dams were to be raised.
4. The space under the keystones of arched bridges, and under the bottom chords of truss-bridges, should be at least 18 feet above the surface of the pools, because the greatest space required for boats is seldom over 16 feet.
5. Finally, a maximum vertical height of from 9 feet 10 inches to 10 feet 2 inches to be given to the wickets of the navigation-pass.

On account of the very small flow in low-water, the surfaces of the pools were always assumed as horizontal.

When the project for movable dams on the Yonne was approved, it was not thought that wickets could be built on the Chanoine system as high as 10 feet, but recently a sluice for navigation has been constructed on the Seine, through the Port á l'Anglais Dam, whose wickets have a vertical height of 12½ feet.

Movable dams on the Yonne.

No. of dam.	Name of work.	Distance in miles.	Lift in feet.	Height in feet above sill.				Lock.		Pass.			Weir.			Remarks.
				Of pass.		Of weir.					No. of—			No. of—		
				Wickets.	Trestles.		Trestles.	Width in feet.	Available length in feet.	Width in feet.	Wickets.	Trestles.	Length in feet.	Wickets.	Trestles.	
	Mouth of Nivernais Canal															
1	La Chainette Dam	0.97	3.97		7.97			27.22	305.04	138.42		36	656.00			Permanent masonry weir—Old Poirée needle-dam.
2	Ile Brulée Dam	1.86	6.06	9.84		6.56		34.44	314.88	98.40	23		82.00	7		Girard shutters on weir.
3	Les Dumont's Dam	3.02	6.06	9.84			8.04	34.44	314.88	98.40	23		82.00		21	Poirée needle-dam on weir.
4	Les Boisseaux Dam	4.08	6.06	9.84			8.04	34.44	314.88	98.40	23		96.43		25	Do.
5	Monéteau Dam	5.05	6.03	9.84			8.04	34.44	314.88	98.24	23		81.80		20	Do.
6	Gurgy Dam	6.92	8.20	10.16			8.04			98.40	23		82.00		21	Do.
	Gurgy cut-off	10.03	8.20 8.20					34.44 34.44	314.88 314.88							Distance shortened 2.79 miles—2 locks.
7	Bassou Dam	10.83	7.21	9.87			8.04	34.44	314.88	115.29	27		96.60		24	Poirée needle-dam on weir.
8	La Gravière Dam	13.05	6.49	9.84			8.04	34.44	314.88	114.80	27		131.20		35	Do.
	Mouth of Burgundy Canal	14.37														
9	Epineau Dam	15.64	3.02		7.87			27.22	593.68	194.18		57	328.00			Permanent masonry weir—Old Poirée needle-dam.
10	Pêchoir Dam	17.25	5.01	9.74		6.46 3.28		34.44	314.88	115.13	27		73.47 183.68	16 28	27	Two weirs and foot-bridge for maneuvering.
11	Joigny Dam	20.29	7.05	9.02		5.41				115.13	27		165.31	36		Weir with movable wicket and foot-bridge.
	Joigny cut-off	22.51	10.66					34.44	314.88							Distance shortened 1.59 miles.
12	Villevallier Dam	25.25	6.26	9.84		6.23		34.44	314.88	115.95	27		165.48	36		Weir with movable wickets and foot-bridge.
13	Armeau Dam	28.22	5.15	9.74		6.13		34.44	314.88	115.29	27		165.48	36		Do.
14	Villeneuve Dam	31.63	5.74	9.78		6.16		34.44	314.88	115.29	27		165.48	36		Do.
15	Etigny Dam	35.21	4.92	9.11		5.51		34.44	314.88	115.29	27		165.48	36		Do.
16	Rosoy Dam	37.95	6.10	9.84		6.23		34.44	314.88	115.29	27		178.59	39		Do.
17	Saint Bond Dam	40.89	5.15	8.88		5.28		34.44	314.88	115.29	27		165.48	36		Do.
18	Saint Martin Dam	43.55	6.03	9.70		6.10 3.28		34.44	314.88	115.29	27		78.23 328.00	17 50		Two weirs and foot-bridge for maneuvering.
19	Villeperrot Dam	46.60	6.33	9.47		5.87		34.44	314.88	115.29	27		165.48	36		Weir with movable wickets and foot-bridge.
20	Champfleury Dam	50.00	6.46	9.73		6.13		34.44	314.88	115.29	27		206.80	45		Do.
21	Courlon Dam	54.39	7.41	9.05		5.44				115.29	27		174.66	38		Do.
	Courlon cut-off	56.96	12.72					34.44	314.88							Distance shortened 2.65 miles.
22	Port Renard Dam	57.25	2.85		7.83			27.22	593.68	211.23		56	295.20			Permanent masonry weir—Old Poirée needle-dam.
23	Barbey Dam	59.88	5.38	9.18		5.58		34.44	314.88	115.29	27		179.25	39		Weir with movable wickets and foot-bridge.
24	Labrosse Dam	62.79	5.64	9.84		6.23		34.44	314.88	115.29	27		197.62	43		Do.
25	Cannes Dam	65.27	6.75	9.75		6.17		34.44	314.88	115.20	27		174.66	38		Do.
	Mouth of Yonne	67.28														

Movable dams on Yonne—Continued.

	Distance in miles.		
Total length via cut-offs.....	67.28	The elevation of low-water mark at Auxerre above tide is..	316.85 feet.
Add length cut-off	7.03	The total fall from Auxerre to Montereau is..	165.84 feet.
		The length of canalized river from Auxerre to Laroche is	14.38 miles.
Total length of river in its natural state...............	74.31	The length of canalized river from Loroche to Montereau is..	52.90 miles.
			67.28

From the table we see—

1. That, in the first section, Auxerre to Laroche, the 8 dams have lifts varying from 4 to 8 feet, and an average lift of 6¼ feet. The two locks of the Gurgy cut-off have each a lift of 8 feet. The 9 pools between the mouth of the Nivernais Canal and the La Gravière Dam have lengths varying from four-fifths of a mile to four miles, with an average length of one mile and a half.
2. That the Epineau pool is common to the first and second sections, and has a length of two and one-half miles.
3. That, in the second section, from Laroche to Montereau, the 17 dams have lifts varying from 2 feet 10 inches to 7 feet 5 inches, and a mean lift of 5¼ feet. The two cut-off locks have lifts of 10 feet 8 inches and 12 feet 9 inches. The 16 pools between the Epineau and the Cannes Dams have lengths varying from seven-eighths of a mile to six and one-third miles, and an average length of three miles.
4. That the distance of two miles between the Cannes Dam and the Montereau bridge is a part of the first pool of the Seine, which ends at the Varennes Dam.

The width of the floor of the navigation-passes of the new dams, with wickets, is from 23 to 33 feet, measured in the direction of the current. The thickness is at least equal to the lift of the dam, and seldom less than 6¼ feet.

Between Auxerre and Joigny the body of the floor rests directly on solid rock or chalk; the masonry was laid dry in coffer-dams. Between Joigny and Montereau the main body is composed of a bed of beton, poured into an inclosure of piles and plank. On this the floor of the sole, consisting of cut and hammered stone, was placed after the water was removed.

In the masonry floor anchors, iron rods, and cast-iron anchoring-plates are imbedded, in order to bind solidly to the masonry the wooden sill against which the breeches of the wickets rest.

The floor of the weir of the new dams has generally a width of 13 feet and minimum thickness of 6¼ feet. It is entirely of masonry, or formed by a wooden box filled with beton and covered by a pavement of heavy stone.

The weir lies between a masonry pier 10 feet thick and 20 feet long, which separates it from the pass, and a masonry abutment, which is connected with the bank by two wing-walls.

Below most of the dams there is an apron, formed of heavy riprap of natural or artificial stone. At some of the dams this riprap is held in place by piles driven in quincunx order.

The passes of the twenty-two new dams on the Yonne are closed by movable wooden Chanoine thickets, 4 feet wide, with 2-inch intervals. During the season of low-water these intervals are covered by planks to make the dam tighter.

It is well known that each wicket is movable around an axis forming the cap of the horse, which itself turns around its sill, whose journals are held in two boxes fastened in the lower face of the sill of the pass. The wicket, when upright, is inclined at an angle of 15° from the vertical, and laps 3 inches against the upper face of the sill. The top is even with the surface of the pool. The axis of rotation of the wicket is so placed that the height of the breech above the sill is $\frac{5}{12}$ of the total height, and consequently that of the chase is $\frac{7}{12}$. The cap of the horse passes through an eye in the head of a prop, whose foot is supported, when the wicket is up, against a cast iron heurter fastened in the sole of the pass. When the wicket is down the prop is retained in a slide, of which the heurter is the head. When it is desired to lower a wicket, the foot of the prop is tripped by a corresponding projection on the tripping-rod, which is moved horizontally on the sole by means of a wheel and gearing placed in the pier or in a wall of the lock, for each pass is managed by two tripping-rods, each of which acts upon one-half of the wickets, beginning at the middle of the pass.

On the other hand, the wickets, when down, are raised by a boat-hook, worked from a boat furnished with windlass and other appliances.

It is quite evident that the trestles, the props, and the tripping-rods are of wrought iron; the slides and the heurters of cast iron.

The weirs of the fifteen new dams between Laroche and Auxerre have been, since their construction, supplied with automatic wickets, with movable counterpoises, on the Chanoine plan. These wooden wickets are 4¼ feet wide, with 2-inch spaces between. The weir can be made tighter by applying joint-covers over the open spaces between the wickets.

Each weir-wicket is movable, like a pass-wicket, around a horse, which carries a prop; and for each wicket there is a heurter and slide. M. Chanoine had even added tripping-rods, which, however, he did not regard as very necessary. The axis of rotation of a weir-wicket being only 2 inches above the one-third the height of the wicket, it was only necessary that the water in the pool should rise from 4 to 6 inches above the top of the wicket to make it swing; the movable counter-weight placed at the foot of the breech, which kept the wicket up when the pool was at its ordinary level, slipped to the chase when the wicket swung. If the level of the pool fell a certain distance the wicket would swing back, and the counter-weight would fall back to the foot of the breech.

This ingenious system was striking in its simplicity, and was accepted at once after the isolated experiments made at a single dam, while specially pre-occupied in devising means for rapidly passing a flood, without exhausting the pool above or injuring the passage of river-craft; but a great disappointment was experienced when the continuous navigation on the Yonne and Seine, between Paris and Laroche, came to be tested. An official order of May 4, 1868, in approving the provisional regulations for the new method of navigation, authorized the engineers to put in operation the dams built on the Seine and the Yonne, between Paris and Laroche. The official order recommended that this delicate work should be undertaken with all the precautions necessary to prevent injury to navigation. The dams on the Seine were raised between the 18th of May and the 7th of June. The first four dams on the Yonne were closed between the 8th and 10th of June, but the raising of the thirteen others was only finished by the 5th of September, after the closing of the canals. A difficulty immediately arose on account of the co-existence of the artificial floods of the Upper Yonne, whose waves came twice a week, and swung a certain number of weir-wickets, which wickets, although called automatic, would not raise themselves until there was a fall of 3¼ feet in the pool above, from which circumstance navigation was much hindered. Thanks to the zeal and activity of the engineers, to the careful watch of the conductors, and to the devotion of the lock and dam tenders, it was possible to master the situation during low-water. With boats and different expedients devised by those in charge of the navigation success was obtained in raising the wickets with sufficient rapidity, and the improvement of the new system was finally apparent and conceded by all. But in the month of August the waters discharged from the canals, and those from violent storms, increased by the artificial flood-wave, produced disturbances in the pools that extended to Paris. In consequence of this experience, care was taken to empty several of the upper pools before the arrival of the artificial flood-wave. On the 22d of October a little rise of 8 inches from the Armançon River arrived at Laroche without being announced, and consequently without the precautions prescribed for an artificial flood-wave having been taken below. A complete derangement resulted at all the weirs and in all the pools from Laroche to Paris. Immediately the engineers proposed to establish above each weir, with movable wickets, a foot-bridge, which, with the aid of a windlass and chains, would permit the management of the wickets and the regulation of the level of the pool above; meanwhile all the dams were opened, and the system of artificial flood-waves was continued freely as formerly. A board of three inspector-generals of Ponts et Chausées, charged with an examination, heard those interested at Joigny, at Sens, at Montereau, and at Paris. They adopted the propositions of the engineers, which, as advised by the General Council of Ponts et Chausées, were approved by an official order of December 28, 1869.

In consequence, during the two seasons of 1869 and 1870 foot-bridges for maneuvering were built above each weir with so-called automatic wickets; and but for the unhappy events at the close of 1870, continuous navigation would have been established between Paris and Laroche by the month of September, 1870; which, however, could not be until the 1st of September, 1871, a year later. Each bridge for maneuvering is composed of wrought-iron trestles, like the trestles of Poirée dams, movable around a horizontal axis at right angles to the axis of the weir. Each trestle is opposite the middle of a wicket. These trestles are connected at their caps by two clamp-bars, which fix the width of the bridge. Between these bars is a wooden flooring, which is raised 20 inches above the level of the pool. The two clamp-bars are the rails upon which rolls the truck that carries the hoisting-windlass. Finally, to this windlass reach two chains, one attached to the head of the chase, and the other to the foot of the breech of each wicket. By the help of the windlass, solidly fastened to one or two treatles and the two chains, every maneuver necessary to regulate the level of the pool—raising lowering, or swinging the wickets—can be performed without fatigue and without danger. In times of flood the trestles of the foot-bridge fall into a recess nearly on a level with the crown of the weir. The planks, the clamp-bars, and the windlass are put in store. The counter-weights have been removed from the weir-wickets as no longer required.

* * * * * * *

This system has succeeded perfectly. At night each lock-tender is warned of the change in the water-surface above his dam by an alarm, put in motion by a float. Soon all the dams will be connected by telegraph, and the system thus completed will prevent surprises.

In consequence of the experience obtained in 1868 on the working of the twenty-nine movable dams between Laroche and Paris, it was decided to improve the navigation of the Yonne between Laroche and Auxerre, with passes opened and closed by movable wickets and weirs provided with foot-bridges and needle-dams. An exception in the arrangement of the weir was made at the Ile-Brulée Dam, near Auxerre-

Which was provided with large shutters, 11½ feet wide, the invention of M. Girard· These shutters, movable around a horizontal axis at the foot, placed on the upper crest of the weir, were supported by props, which were the piston-rods of the same number of inclined pumps, firmly fastened to the floor. These pistons are put in motion by the water which comes by pipes under water, communicating with a reservoir supplied by a turbine, which is itself put in motion by the fall at the dam. Finally the dam of La Chaînette, at Auxerre, at the head of river-navigation, has a stationary weir, and a pass only closed by a needle-dam.

To sum up. Of the 25 movable dams established on the Yonne between Auxerre and Montereau three are on the Poirée system proper; there remains but one on the Chanoine system proper; 22 have passes with Chanoine wickets, but the weirs have different systems; 15 weirs have movable wickets with foot-bridges for maneuvering, 6 have needle-dams on the Poirée system, and 1 only has large Girard shutters. At present the working of all these dams is easily managed, without danger to the attendant, and surprises are no longer to be dreaded, thanks to the floats with alarms at each dam, and the telegraphic communication from dam to dam.

There are 26 locks between Auxerre and Montereau, while there are only 25 movable dams, because the Gurgy cut-off, just above the dam of the same name, has 2 locks. Of these 26 locks 23 are new, and their chambers have a width of 34¼ feet, and an available length [between chord of lift-wall and recess of lower gate] of 315 feet, so as to receive six canal-boats coupled two by two, and two rafts coupled together; 2 of the 3 old locks, those of Epineau and Port Renard, have chambers 27 feet wide, with an available length of 594 feet; they therefore can receive six canal-boats and two rafts one after the other; a single lock that at La Chaînette, has a chamber 27 feet wide, with an available length of 304 feet. This lock receives three canal-boats or one raft; which is not inconvenient, for reasons given before.

The three locks of La Chaînette, Epineau, and Port Renard have the faces of their walls of cut and hammered stone; the river-wall has a thickness of 8 feet 2 inches.

Thirteen of the 15 new locks below Laroche have only their extremities and the gate recesses in masonry with vertical faces; the rest of the chamber is bounded by two paved masonry slopes with 45° inclination. [These slopes were originally made of dry stone resting upon beton, but several accidents and slides caused the dry stone to be replaced by masonry, both here and for the upper surfaces of dikes.] This rock-work, of scabble-stone for 10 locks and rough for 3, rests on a mass of beton or masonry, founded on solid rock or sustained by a line of piles and sheeting; the dike which forms the river-wall of locks in the river has a thickness of 10 feet at the top, with an exterior slope of rubble on an inclination of three base to two perpendicular; the foot of the exterior slope is protected by a line of piles and sheeting, or by heavy stones, when it does not rest on rock. The top surface of the dike is covered with masonry. This dike, which is of earth, and contains a core 6¼ feet thick of puddled clay, is generally water-tight. The 2 locks of Péchoir and St. Martin have on the land side of their chambers a slope of 45°, and on the river side a vertical wall of masonry 8 feet thick, with an enlargement opposite the lower gate to contain the chamber in which are placed the wheels and pinions which work the tripping-rod of the press.

Of the 8 new locks between Auxerre and Laroche, two, those at Monéteau and Bassou, are on the same plan as those at Péchoir and St. Martin. The 6 other locks have their chambers bounded by two vertical masonry walls, and for the 4 locks in the river, the river walls are 8 feet thick.

The cost of the forgoing works was as follows:

	Francs.	Dollars.
The reservoir des Settons	1, 327, 680	152, 259
Seven locks and dams, between Auxerre and Laroche, at 317,000 francs, ($60,230)	2, 219, 000	421, 610
One dam without lock between Auxerre and Laroche	140, 000	26, 600
Eight locks and dams, between Laroche and Sens, at 462,000 francs, ($87,780)	3, 696, 000	702, 240
One dam without lock between Laroche and Sens	170, 000	32, 300
Seven locks and dams between Sens and Montereau, at 561,000 francs, ($106,590)	3, 927. 000	746, 130
One dam without lock between Sens and Montereau	200, 000	38, 000
12,715 meters (7.9 miles) of wide cut-off, at 238.45 francs ($45.30) per meter	3, 032, 000	576, 080
Miscellaneous work: protection of banks, dredging, damages, &c.	3, 440, 358	653, 668
	18, 152, 038	3, 448, 887

The total length of the Yonne, in its natural state, between Auxerre and Montereau, is 74.30 miles; the length of the improved river, measured by the cut-offs, is 67.28 miles; the cost per mile of improved river is, therefore, $51,261; but if the cost of the reservoir des Settons be deducted, the cost per mile becomes $48,998.

NAVIGATION OF THE UPPER SEINE.

The Upper Seine extends from Marcilly, at the mouth of the Aube, to Paris; but the portion between Marcilly and Montereau is generally called the Little Seine, while that between Montereau and Paris is the Upper Seine proper.

During low water the depth of the Little Seine varies from 8 to 12 inches, and that of the Upper Seine from 20 to 24 inches. The greatest flood known had an elevation at Paris, above low water, of 23½ feet.

The slope of the Little Seine in low water averages 14 inches per mile, and that of the Upper Seine 13 inches per mile.

On the Little Seine there is a continuous navigation between the mouth of the Aube, at which place the Upper Seine Canal enters the river, and Nogent, by means of the cut-off between Marcilly and Nogent and the two dams of Conflans and Nogent; but from Nogent to Montereau there are only four dams, which are used to give artificial flood-waves as far as Montereau. The navigation of the Little Seine is, therefore, not very important, but it is expected that, before long, the same improvements will be introduced here as on the main Upper Seine and on the Yonne. Although the navigation of the Upper Seine, between the mouth of the Yonne and Paris, has always been very important, until September, 1871, it was intermittent for three-fourths of the year and largely dependent upon the artificial floods from the Yonne. This condition of affairs has been ended by the establishment of 12 movable dams between Montereau and Paris.

In examining the question of improving this navigation, it was observed that the effect of an artificial flood-wave was insufficient after it had traversed a distance of 19 miles.

In 1859, 3 dams, in accordance with plans of M. Chanoine, were ordered at Champagne, (one mile below the mouth of the Canal du Loing,) at Melun, and at Evry; and in 1860, 9 others were ordered at Varennes, La Madeleine, Samois, La Cave, Les Vives-Eaux, La Citanguette, Le Coudray, Ablon, and Port-à-l'Anglais.—(See the profile Fig. 52.)

The 12 large movable dams just mentioned were built between 1859 and 1864, after the system of M. Chanoine, that is, with movable wickets 4 feet wide for the pass, and automatic wickets 4 feet 3 inches wide for the weir; the interval between two wickets was 4 inches; a single dam, that at Melun, retained for the weir the needle-dam which was already built across the right arm of the Seine. The navigation-passes, which are of masonry, vary in width from 132 to 212 feet; the wooden sills, solidly built into a floor 32¼ feet wide, are 10 feet below the level of the pool and 2 feet below low-water line. The new weirs are from 197 to 229 feet long; their sills are 20 inches above low water; the floor, 13 feet wide, is formed of a wooden casing filled with béton, with wooden ties on top, between which is inclosed a masonry pavement; each weir is contained between a pier 10 feet wide, which separates it from the pass, and an abutment which connects it with the bank.

The locks have chambers 39 feet wide, with an available length of 587 feet, so as to receive at least twelve canal-boats or four rafts.

The extremities and the gate-recesses of the locks are built of masonry; but the revetments of the chambers are simply of paving made with rough stones laid dry, resting upon a core of béton placed under water and inclined at an angle of 45°; the dike on the river side, which has a puddled core, is 10 feet wide on top; its outer slope is revetted with rough stone laid dry over riprap. The Port-à-l'Anglais lock has masonry walls with vertical interior faces. The miter-sill is placed at least 5¼ feet below the surface of the pool below, which is assumed as horizontal.

The upper surfaces of the dams and of the locks are at least 16 inches higher than the surfaces of the pools above them.

The test made in 1868 of the continuous navigation, which has been mentioned before, in connection with the movable dams on the Yonne, had shown the unreliability of the automatic weir-wickets, and the lack of solidity of the revetments of the lock-chambers, which had been made of rough stones laid dry, and often crumbling under the action of frost. The official order of December 28, 1868, approved of the complementary works which had been considered necessary, and which consisted chiefly—

1st. In lowering the lower miter-sill of the Port-à-l'Anglais lock, and in reconstructing the chamber of this lock.

2d. In the establishment of foot-bridges for maneuvering, made with trestles placed just above all weirs, with Chanoine automatic wickets.

3d. In the consolidation of the paved slopes of the lock-chambers.

4th. In the establishment of a line of telegraph between the dams.

The changes above mentioned were all made by September, 1871, having been delayed by the war and the communist troubles. All the works are firm and solid, and have succeeded perfectly.

The following table gives the principal dimensions of the dams and locks:

Movable dams on Upper Seine.

No. of dam.	Name of work.	Distance in miles.	Lift in feet.	Height in feet above sill.				Lock.		Pass.		Weir.			Remarks.
				Wickets of pass.	Of weir.		Wickets of sluice.	Width between walls in feet.	Available length in feet.	Width in feet.	No. of wickets.	Length in feet.	No. of—		
					Wickets.	Trestles.							Wickets.	Trestles.	
	Bridge of Montereau	0	....	....	....	....	....	....	....	....	....	....	....	....	
26	Varennes Dam	2.24	4.98	9.54	6.26	....	....	39.36	590.40	132.51	31	197.78	43	....	Weir with movable wickets and foot-bridge.
27	La Madeleine Dam	5.62	5.48	9.51	6.23	....	....	39.36	590.40	132.51	31	197.78	43	....	Do.
	Loing Canal	8.54	....	....	....	....	....	....	....	....	....	....	....	....	
28	Champagne Dam	9.95	5.37	9.54	6.23	....	....	39.36	590.40	149.57	35	197.78	43	....	Do.
29	Samois Dam	16.00	6.82	9.54	6.26	....	....	39.36	590.40	85.61 85.61	20 20	198.77	43	....	Do.—Two passes.
30	La Cave Dam	20.87	6.13	9.58	6.20	....	....	39.36	590.40	149.57	35	220.74	48	....	Do.
31	Melun Dam	26.41	4.39	9.51	....	8.04	....	39.36	590.40	213.53	50	131.20	....	35	Weir replaced by needle-dam across right arm of Seine.
32	Vives-Eaux Dam	30.08	4.79	9.54	6.26	....	....	39.36	590.40	162.36	38	211.56	46	....	Weir with movable wickets and foot-bridge.
33	La Citanguette Dam	34.18	4.66	9.61	6.23	....	....	39.36	590.40	162.36	38	211.56	46	....	Do.
34	Le Coudray Dam	38.59	5.97	9.61	6.23	....	....	39.36	590.40	166.62	39	229.93	50	....	Do.
35	Evry Dam	44.30	5.05	9.45	6.26	....	....	39.36	590.40	166.62	39	229.93	50	....	Do.
36	Ablon Dam	51.38	6.10	9.54	6.23	....	....	39.36	590.40	179.42	42	229.93	50	....	Do.
37	Port-à-l'Anglais Dam	58.34	9.84	9.54	6.23	....	12.14	39.36	615.00	179.42 94.14	42 26	124.31	27	....	Navigable pass and navigable sluice.
	Fortifications of Paris	60.86	....	....	....	....	....	....	....	....	....	....	....	....	

PORT-À-L'ANGLAIS DAM.

On account of the great distance—fifteen miles—between the Port-à-l'Anglais Dam, situated above Paris, and the Suresnes Dam, situated below, and in consequence of the final abandonment of the project of establishing a dam in the city itself, the official order of December 28, 1868, directed the lowering of the lower miter-sill of the Port-à-l'Anglais lock and the reconstruction of the chamber-walls. Consequently a plan for lowering the lower miter-sill 3½ feet, and for bounding the lock-chamber by two masonry walls with vertical faces, was approved May 12, 1869, and the work was executed in 1869 and 1870.

While the work of lowering the lower miter-sill of the lock of the Port-à-l'Anglais Dam was in progress, navigation was kept up through a breach 115 feet wide made in the weir near the right bank, where the channel formerly ran. An official order of February 25, 1870, approved a project presented December 18, 1869, by the engineers, to construct in this breach a sluice for navigation having its sill 2 feet 4 inches below the sill of the pass, and closed by wickets 12 feet 2 inches high. The works were executed in 1870, and were almost entirely completed a few days before the investment of Paris. It was only in 1871 that the sluice could be tried, as also the whole work at Port-à-l'Anglais.

This sluice, 94 feet long, is closed by 26 wickets 3½ feet wide, and having their tops 4 inches below the level of the upper pool, so that a film of water 4 inches in depth flows over them; but it is easy to add a piece of plank to the tops of the wickets, which now have a vertical height above the sill of 12 feet 2 inches, and which would then have 12 feet 6 inches. A foot-bridge, supported by strong wrought-iron trestles, 15 feet 8 inches high, is established above, in order to handle the wickets, which are thrown down by means of a tripping-rod.

The original intention was to establish a foot-bridge above the pass of the Port-à-l'Anglais Dam, which would have had the advantage of permitting the person in charge to cross the river on foot when the dam was closed; but the matter was postponed, and is now altogether abandoned, because in times of ice and break-up it is essential to have the means of opening any part whatever of the dam; for, during the nights of the 7th and 8th of December, 1871, there happened a sudden and exceptional degree of cold, (21°,) and the dams being all up, were encased in ice before it was possible to open anything; but long before the ice melted, the wickets of the pass, which were not preceded by trestles, were cleared, and before the break-up these wickets were lowered, which enabled the cakes of ice to pass through without injuring the dam. With a complication of wickets and foot-bridge, it might not have been possible to have attained the same result.

At the Port-à-l'Anglais Dam a trial is being made of what are called "Papillon valves," which, when placed in the chase of a wicket, open of themselves when the water reaches a given height, and easily close when it falls below it. By using a number of these, a much larger discharge than is now possible could be accommodated before it became necessary to swing the wickets of the weir.

The cost of the work on the Seine has been as follows:

5 locks and dams between Montereau and Melun, at 809,283 francs, ($153,764)	4,046,416 fr.=$768,819
6 locks and dams between Melun and Ablon, at 864,235 francs, ($164,205)	5,185,411 fr.=$985,228
1 lock and dam at Port-à-l'Anglais	1,580,733 fr.=$300,339
Miscellaneous, dredging, dikes, engineering, &c	3,541,500 fr.=$672,885
Total	14,354,060 fr.=$2,727,271

Length of the river, Montereau to Paris, 61 miles.
Cost per mile of improved river $44,931.

MEANS OF TRACTION AND DIMENSIONS OF RIVER-CRAFT.

Under the system of artificial waves all down-stream traffic floated with the wave, and up-stream boats were towed from Paris to Montereau by tugs that pulled themselves along by a sunken chain; above Montereau they were pulled by horses. Since the establishment of continuous navigation both of the above methods continue in use, and steamboats that themselves carry freight made their appearance on the river.

As the new navigation has just begun, boats do not yet draw all the water available. The average load of a canal-boat is 100 tons, and the maximum load is 200 tons, while large river-barges carry from 300 to 350 tons.

Rafts are generally 300 feet long, 16 feet wide, and from one foot and three-quarters to two feet in depth. They contain about 120 tons of timber. Canal-boats are 100 feet long and 16 feet wide, and large river-barges are from 115 to 130 feet long, and from 23 to 26 feet wide. (The latter are almost exactly the size of the coal-barges used on the Ohio.)

CONCLUSIONS.

The following are the conclusions of Mr. Cambuzat in reference to the adaptability of the various systems of movable dams that have been tested on the Seine and Yonne:

> To sum up, in a system of continuous navigation—
>
> 1st. When the lift is small, not exceeding 5 feet, it is advantageous to use Poirée dams, with foot-bridge and needles and a permanent weir, the foot-bridge being raised from 10 to 12 inches above the surface of the pool.
>
> 2d. For lifts from 5 to 8 feet, dams should be used whose passes are closed by Chanoine wickets, and whose weirs are surmounted by Poirée trestles and needles, and whose foot-bridges are raised from 10 to 12 inches above the surface of the pool.
>
> 3d. For lifts exceeding 8 feet, large wickets worked by the aid of a foot-bridge can be safely used; but in order to guard against surprises in times of flood, of thaws, and of break-ups, the sill of the pass should be sufficiently raised to receive wickets maneuvered by the aid of a boat, and the weir should be surmounted by trestles with needles.

DE LAGRENÉ ON MOVABLE DAMS.

After the above had been translated, a copy of De Lagrené's recent work, "*Cours de Navigation Intérieure, Fleuves et Rivieres, Paris*, 1873," was received from the publisher, which contains full information about the Girard shutters, which are noticed in the *Annales*, but are not represented in the plates, and also gives drawings of several other systems. Being the latest work on the subject, it is believed to contain a complete summary of the progress of invention in such matters up to the present date.

The following is taken from this work:

BEAR-TRAP GATES—(AMERICAN SYSTEM.)

The American system, which I am about to describe, is defective in more than one respect, but nevertheless it is interesting to become acquainted with it, because it has probably served as the starting-point in seeking the more perfect methods. (See Figures 1, 2, 3. The drawings of this system, as given by De Lagrené, show, in addition to the two gates, a Thénard counter-shutter, which is placed in the sluice above the gates. As the text sufficiently explains the position and use of this additional member, it has not been considered necessary to redraw the figures, which were taken from Hagen. The circumstances under which the bear-trap gates are used on the Marne are different from those under which they were originally used on the Lehigh, and hence the necessity for the additional shutter.)

At the dam of Neuville au Pont, on the Marne, in the department of the Upper Marne, there is a sluice with an opening of 29 feet 8 inches, which is provided with American gates.

The system is composed of two gates somewhat like those used to close lock-chambers, except that their quoin-posts are horizontal, and are placed across the sluice in a chamber excavated in the floor.

The distance between the two quoin-posts is less than the sum of the width of the gates, so that when they lie down the up-stream gate rests on the down-stream one.

The sill of the floor is 3 feet below low-water, and 9½ feet below the surface of the upper pool.

The length of the gates is 31 feet; they therefore extend 8 inches into the face of each pier, and their motion takes place in a recess, against the edges of which each end of the gates is supported when their movement is ended.

The piers of the sluice are pierced from above to below by culverts, whose ends can be closed at will by means of valves placed in wells.

Above the gates shutters are placed which can temporarily close the sluice. These shutters have their axis of rotation fixed on the floor, and they fall up stream. When they are raised they are held nearly vertical by two retaining-chains fastened to the floor; when they are laid down they are held in a horizontal position by spring-latches, which are fastened on their upper surfaces, and catch of themselves on a stop-bar, which is fixed transversely on the floor. A slight rotation of this bar is sufficient to disengage the latches, and thus free the shutters.

These shutters will at once be recognized as the counter-shutters of the Thénard system, and their assistance is necessary in order to start the American gates, as I will proceed to explain.

In order to shut the sluice, the attendant commences by closing the down-stream valves of the culverts in the piers; he then opens the up-stream valves and disengages the latches of the shutters; the latter are immediately brought up by the current; they close the sluice and stop the flow of water through it; the lower pool lowers and the upper pool rises. This difference of level causes a pressure under the gates, which finally raises them until they meet the wooden heurters placed in the recesses in the piers.

The water, still rising in the upper pool, soon flows over the shutters and fills the space between them and the gates; the former being thus relieved from the pressure that kept them up yield, partly to the effect of their own weight, and partly to the pull of the retaining-chains, and fall down on the floor, where their latches again catch under the stop-bar.

The maneuver of opening is still simpler. It is limited to closing the up-stream valves in the piers and opening the down-stream ones. The water under the gates loses the pressure of the upper pool, and a portion of it flows into the lower pool, and the gates lie down in their chamber.

Experience shows that the gates begin to rise when the fall from the upper to the lower end of the sluice is at least two feet. The time used in closing the sluice depends, therefore, upon the time needed by the river to generate this fall. The maneuver of opening only lasts three minutes, and the gates immediately sink.

The American system, which has just been described, gives rise to the following remarks:

In the first place, the gates are not balanced around their axes of rotation like Desfontaines' wicket, nor are they received by a water-tight cavity, and, even after immersion, they retain considerable weight, which produces a decided moment of resistance.

The calculations which the author gives show that the total weight of the upper gate is 20,840 pounds, and that of the lower or counter gate is 49,756 pounds. The width of the upper gate is 13 feet, and that of the lower gate, measured from its axis of rotation to the axes of the friction-rollers, at its upper end, is 20 feet. When the gates are down, the center of the friction-roller of the lower gate is 5 feet 7 inches from the axis of rotation of the upper gate. When the gates are down the pressure that must be applied to the under surface of the lower gate in order to start them is 709½ pounds per running foot, or 35½ pounds per square foot.

Thus the mere weight of the apparatus requires a difference of level of nearly 7 inches in order to put the gates in motion.

In this system there are other resistances to raising. Both the gate and the counter-gate turn around a wooden axle 31 feet long, which is held by eleven collars of 1 foot interior diameter. This large diameter is the cause of considerable friction. Moreover, between the collars each axle turns in a hollow cut-stone quoin; consequently we find here a double difficulty; in fact, if we leave much play between the axle and the hollow quoin, imitating the practice with lock-gates, we cause considerable leakage, and the loss of pressure of the sustaining water may become too great. If, on the other hand, we reduce the play to fractions of an inch, the least entrance of sand or sediment will cause friction that cannot always be overcome.

Each axle, although perfectly true when the gates are built, may lose its shape after a little while, and by its bending may produce abnormal pressure on some of the collars.

The friction of the axles is not the only thing that must be met. There are besides, seven rollers at the upper end of the counter-gate.

The lever-arm of the lifting force, exercised by the counter-gate, under the gate, is very feeble at the beginning of the movement.

Finally, the leakage under each of the four edges of the gate, and of the counter-gate, must be considerable, and there must be a perceptible loss of pressure in the water that put the apparatus in motion.

I would further remark that the lowering of the gates is not readily done, unless the angle which is made at the top between the gate and the counter-gate when they are up is very obtuse, which makes it necessary to give a great width to these members. This great width increases the resisting moments of the apparatus, as well as the loss of pressure in the water, which is the motive force.

These remarks explain why it has been thought necessary to complete the American system by adding to it a provisional closing apparatus by means of up-stream shutters. These shutters protect the gate from the dynamic pressure due to the current, and, besides, they generate the fall which is necessary to raise the gates, which, as we have seen in what precedes, must be at least 2 feet. The same object could have been attained by a needle-dam, which would also have been useful for other things, as I have explained in the preceding chapter.

The American sluice of La Neuville, considered by itself as consisting of two piers, the floor, the double system of closing, and the down-stream apron of riprap, cost 71,595 francs, ($13,603.)

The American dam is now completely abandoned, and almost entirely forgotten in America. (Malézieux: Public works in the United States, p. 280.)

The substance of what M. Malézieux says is that, when he asked American engineers about their movable dams, they did not know what he meant. Only the older ones recollected having seen on the Lehigh a movable gate, whose sole object was to produce artificial waves for bringing down timber.

At present the Lehigh has only permanent dams below Mauch Chunk. Above—between Mauch Chunk and White Haven—there are only ruins, which either show the violence of the floods or the lack of experience of their builders.

DRUM-WICKETS WITH INDEPENDENT COUNTER-WICKETS.—CUVINOT SYSTEM.

After studying the Desfontaines system, M. Cuvinot proposed to endeavor to improve it while fulfilling the following conditions:

1st. To reduce the length of the counter-wickets.

2d. To lessen the loss of pressure in the water that moves the apparatus while it is passing through the drums.

3d. To make the wickets independent, so that those which are to be lowered in order to regulate the level of the pool may be chosen at will throughout the length of the dam, so that the cataract may be divided.

4th. To obtain stability for the wickets, so that none of them can rise or fall without the intervention of the dam-tender, whatever may be the variations in level above or below the dam.

We will assume for discussion a height of dam of 9 feet 10 inches.

The navigable pass is supposed to be provided with movable apparatus of any system whatever—Chanoine wickets, for example—and the following is the manner in which the inventor proposes to construct the weir:

The permanent sill of the weir is placed at 3 feet 3 inches above low-water.

In the body of the masonry three large cavities or longitudinal conduits are prepared, which are parallel to the axis of the weir, and are arranged as follows, beginning on the up-stream side, (see Plate II:)

First, a rectangular conduit, 4 feet 1 inch wide, and 6 feet deep.

Secondly, a conduit of a nearly circular shape, whose bottom is likewise 6 feet below the permanent sill, and whose width at the level of the floor is 9 feet 7 inches.

Lastly, a third conduit similar to the first. These three cavities are separated by two division-walls, each 2½ feet wide.

The up-stream rectangular conduit is in constant communication with the upper pool. The down-stream one is always in communication with the lower pool. These two aqueducts, whose tops are covered, perform parts analogous to those of the upper and lower conduits in the Desfontaines system.

The half circular conduit is divided by diaphragms into compartments 3 feet 7 inches long, completely independent of each other.

Two consecutive diaphragms support, in their middle, the axis of rotation of a counter-wicket, which moves in the drum, and describes an angle of 130°. The two arms of the counter-wicket, after inclosing the axis of rotation, are prolonged above the plate that covers the drum, making a bend of 20°. These extensions become two props, which are provided, at their ends, with friction-rollers.

The diaphragms also support the axis of rotation of the wicket. This axis is placed further up stream than that of the counter-wicket, and at a slightly higher level, so that when the wicket is down it covers the props, and its end rests on the friction-rollers.

Each compartment of the circular conduit communicates with the upper conduit by a hole in the dividing-wall, which always remains open.

Each compartment of the circular conduit is, at will, put in communication with the lower conduit by a hole in the dividing-wall, and this hole is opened or shut by means of a valve, according to the needs of the service.

We can now explain the working of the apparatus. When the counter-wicket turns around its axis of rotation under the influence of the hydraulic pressure, the props take the wicket in reverse, and make it describe an angle of 70°. In its last position, and throughout its movement, the wicket rests upon the rollers of the props.

If the new weir had no other arrangements than those just described, its maneuvering would not differ from that of the Desfontaines weir. The combination by which the independence of movement of the wickets can be assured is yet to be described.

Let us suppose the dam down, and let us imagine that each one of the holes connecting with the lower conduit is closed by a water-tight valve; whatever may be the pressure brought to bear upon the up-stream faces of the counter-wickets, none of them will budge, for there is a play of one-seventh of an inch around the perimeter of each, and consequently there is an equality of pressure on the two faces of each counter-wicket. As soon as one valve is opened the counter-wicket of the compartment, thus relieved from pressure on its down-stream side, will commence moving, and will set up the wicket which it controls. The valve once closed, the equilibrium of the pressure will be immediately re-established on the two faces of the counter-wicket, and the wicket, pressing on the rollers with the pressure due to the lift of the dam, will carry back the counter-wicket to its first position as it falls down itself. In order to permit this movement of lowering, it is necessary, even when the wicket is up, that there should be a water communication between the up and down stream faces of the counter-wicket. Thus, contrary to what happens in the Desfontaines system, the counter-wicket, when the wicket is up, does not make a water-tight connection with its seat, but is supported on a certain number of points, so as to permit leakage around its perimeter.

Maneuvering will then be reduced to that of the valves, of which I have just spoken, and can easily be controlled by means of a rod with projections, which is placed in the lower conduit. By suitably arranging the projections of this rod, all the wickets can be lowered in succession, in whatever order may have been determined in advance.

The raising will be done in inverse order.

The axis of rotation of each valve is provided with a projecting finger, (Fig. 66,) whose direction is parallel to that of the valve. This finger, when pushed by the projection, remains horizontal while the projection rests upon it.

When the projection is drawn back by a movement of the rod, the valve, which is now free, is swung down by the counter-weight, which is fastened to it for this object.

It has been foreseen that a case might occur in which this counter-weight would be insufficient to overcome the adhesion of the India-rubber facing and to cause rotation.

A counter-finger, likewise fastened to the axis of the valve, and at right angles to the finger, receives the push of the tripping-rod through a stud, which forms a kind of counter-projection. When the movement has once begun, the counter-weight will always suffice to swing open the valve, and the counter-finger will not be in the way of the advance of the bar while the movement of lowering the wickets is in progress.

This brief description already shows that, by placing the upper and lower conduits outside of the drums, it is much easier to increase their cross-section; this is an important consideration in order to avoid loss of pressure.

It can also be seen that the relative positions of the wicket and the counter-wicket lead, as a first consequence, to the possibility of a reduction of the length of the latter. In fact, for a dam constructed under conditions similar to that at Joinville, a lift of 6 feet 7 inches compels the adoption of a counter-wicket descending to 8 feet 2 inches below the permanent crest. In the system described in this chapter, the counter-wicket, describing an angle nearly double that described by the wicket, can furnish the same quantity of effective work with a shorter length, and the depth of the excavation in the masonry is thus diminished about 2 feet.

The weir is contained between two piers or abutments, which are penetrated by the two rectangular conduits; they end in aqueducts, which pass through the entire length of each bounding wall, and are perpendicular to the direction of the dam. These aqueducts have three valves: The first, commencing up stream, is between the opening for taking water and the end of the raising-tube; it is seldom closed, except during floods of muddy water, and during the cleansing operations, which will be described next. The second valve is between the two conduits, and is generally closed. Lastly, the third valve is placed below the emptying-conduit, and is always open, except in rare cases.

As a rule, the up-stream conduit is left in constant communication with the upper pool at both ends, and the lower conduit in communication with the lower pool.

The only work to be done to regulate the level of the pool consists, as I have said, in shifting the tripping-rod.

If the upper rectangular conduit should receive sedimentary deposits, it is only necessary to close the upper valve of one of the piers and to open the middle valve of the same pier. A very rapid current will be formed in the conduit, and will clean it out. A similar maneuver will assure the cleanliness of the lower conduit.

However, deposits, if they should occur, need not be dreaded, since they will be localized in the two conduits at a distance from the drums, and they could have no injurious effect upon the march of the counter-wickets, except by slightly diminishing the cross-section of supply or discharge.

The establishment, above the wickets, of a line of trestles, carrying a foot-bridge, is demanded by general reasons which apply to all wicket-dams; in fact, it is important to give the lock-tender an easy circulation from one shore to the other. In addition, the line of trestles permits the construction of a temporary dam for repairing, either with the view of momentarily replacing the wicket-dam by one of needles, or of moderating the current by means of a screen of needles placed in front of lowered wickets, or of regulating the inclination of the wickets, as I have explained in speaking of the Joinville Dam. In conclusion, although a foot-bridge above is not indispensable for the Desfontaines or the Cuvinot Dam, I think that there ought to be no hesitation about establishing one.

The author then calculates the amount of the forces that act on the different parts of the apparatus, selecting the wicket nearest the pier, as in this system this should be the last wicket raised. Even in this case there would be no difficulty in raising the wicket. There may be some trouble with the friction-rollers, but the proper test of the system is to try it, which, apparently, has not yet been done.

He suggests that the masonry in the weir might be greatly reduced by omitting the upper and lower conduits, and opening direct communication between the drums and the upper and lower pools. The objection to this is that the drums might be filled with sediment and vegetable matter brought down by the current.

POIRÉE NEEDLES.

M. De Lagrené states that experiments with needles having sections of the form of regular or semi-regular hexagons have shown that, owing to the bending of the needles and to practical difficulties in placing them in the positions which theory would indicate, it has been decided to give up these sections and to return to the square. He suggests for trial needles shaped like a T, which are to alternate with square needles.

This solution, however, does not appear altogether satisfactory; and he also proposes for trial needles whose upper sides are slightly rounded and are provided with strips of India-rubber, with the view of overlapping adjacent square needles. The upper portions of T-needles and of those with India-rubber flaps ought to be square, but this will not be objectionable, as the greatest leakage is nearest the sill. He also suggests the use of hollow needles made of planks, for which he gives the necessary calculations. Such needles would have to be handled by mechanical means. Two such needles were tried in the pass of the Melun Dam, in September, 1872, when there was a fall of 7 feet 2 inches, and there was no difficulty in putting them in place. Sections of these forms are given on Plate 10, Fig. 62.

The author thinks that intermediate supporting-bars are necessary in high needle-dams, and states that since their adoption on the Lower Seine, in 1868, the breaking of needles has almost entirely ceased.

M. Cadot suggested that it might be advantageous to have trestles with two stories of needles. He proposed to fasten pins to the upper legs of the trestles, a little below the tops of the lower needles, and to place on them the sill for the second story of needles. This sill should be of T-iron, hooked on to these pins, and should be put in place after completion of the lower story of needles. This plan would make two foot-bridges necessary at different heights, and it might happen that the removal of the upper story of needles would not sufficiently lower the water to expose the lower foot-bridge. That, however, might be remedied by limiting the two-story arrangement to a part of the dam, and making the rest of long needles. If the removal of the latter did not suffice to uncover the lower bridge, the needles of the lower story would have to be removed by a boat. This plan, although not yet in use, seems to promise good results.

SHUTTERS WITH PONTONS.—KRANTZ SYSTEM.

The plan of dam proposed by Chief Engineer Krantz in 1868, and now in course of construction on the Lower Seine, at Port Villez, suggests new combinations, which I will explain from the description of the inventor which accompanied his plan.

M. Krantz first decided on the principle that every movable dam should satisfy the following conditions:

1. It should be maneuvered by the aid of the natural forces of the water-course, properly brought in play, and without exposing the attendants to any risk.
2. The whole apparatus should at all times be subject to human control.
3. It should, spontaneously, correct the slight changes of level in the pools, and should rarely require the intervention of man.
4. It should only be composed of strong parts, capable of resisting violent shocks.
5. It should only require for its establishment constructions similar to those which are habitually built on our rivers.
6. It should be sufficiently tight.
7. It should be applicable to lifts greater than those of the present dams.

Then comes the description, which I copy *verbatim*, allowing the inventor to speak for himself:

"The dam which we are about to describe is planned to sustain a lift of 9 feet 10 inches.

"When lowered, it should not project above the horizontal plane drawn 2 feet 7 inches below low-water.

"We could easily have chosen a different relief, as the system is well adapted to it. But, on the one hand, the depth of 2 feet 7 inches is that of the navigable passes constructed on the Lower Seine, particularly at Suresnes; and, on the other hand, a lift of 9 feet 10 inches is that of our highest needle-dams. By choosing these dimensions we render the comparisons which we intend making more simple and more conclusive.

"The essential parts of the dam are: (Plate 12, Figures 67, 68, 69, 70.)

"1. The lockette, (*éclusette*, or little lock,) by which the water which serves to work the apparatus is distributed under the proper pressure.

"2. The dam proper, which includes the ponton with the upper wicket, and its valves, and the water-conduit.

"The lockettes are placed at the ends of the different sections of the dam, each of which may have as great a length as 300 feet.

"Their number, and the spaces between them, depend upon local circumstances, with which we have no concern at present.

"As to the dam, whatever be its importance, it is divided into elements 9 feet 10 inches long, which act simultaneously under the action of the same forces, while at the same time preserving a mutual independence.

"The lockettes are of metal, and rest upon a masonry base. They are hollow, and communicate with the upper and lower pools.

"Two sets of valves, with vertical axes, placed near the ends, permit at will the interruption or the establishment of communication between the central part of each lockette and the pools.

"Whence it follows that the lockette is, in fact, what its name indicates—a kind of lock, of small size, in the chamber of which one can, at will, by a suitable movement of the valves, maintain either the level of the upper pool, or that of the lower pool, or an entirely different intermediate level.

"The side wall of the lockette which adjoins the dam is pierced at the height of the conduit by a rectangular opening, through which flows the water destined to raise the apparatus, or by which it escapes when the dam is to be lowered.

"This opening is 11½ feet long and 2 feet wide, and has a surface of 23 square feet.

"The conduit extends under the entire length of the dam. It is connected at its ends, by means of the opening just mentioned, with the chamber of each lockette.

"By them it can be put in communication sometimes with the upper pool, sometimes with the lower pool. By them it can receive water coming from a level intermediate between those of the two pools.

"The opening which forms the communication between the chambers of the lockettes and the conduit is always clear. This communication is never interrupted.

"The conduit is trapezoidal in form; its down-stream wall is vertical, and stops 2 feet 7 inches below low-water; its up-stream wall is formed by a part of a cylinder, concave down stream, and described with a radius of 14 feet; this wall rises to 3 feet 4 inches below low-water.

'The width of the conduit on the bottom is 14 feet 9 inches; its depth below low-water is 8 feet 7 inches.

"The section of the conduit of a dam of the importance of that which we have described is 122 square feet.

"The office of the conduit is to distribute in all parts of the apparatus the water of different pressures, which is the effective force.

"We will now examine the appliances by means of which this force acts to work the dam.

"The essential organ is the ponton.

"It floats in the conduit and receives the immediate action of the water.

"The ponton is empty, and the volume of water which it displaces constitutes an ascending force of such a character as to suppress entirely, or partly, the weight of the apparatus.

"Its general form is a rectangle rounded at its ends.

"Its dimensions are:

"Length, including borders	9 feet 2 inches.
"Width, at right angles to dam	13 feet 5 inches.
"Thickness	3 feet.
"Weight, including iron-work	14,405 lbs.
"Volume of water displaced	21,839 lbs.

"Each ponton, then, tends to rise with a force equal to 21,839 lbs. — 14,405 lbs. = 7,434 lbs.

"We will see later under what conditions this ascending force acts.

"Each ponton is fastened by two hinges, with horizontal axis, placed a little below the upper down-stream angle of the water-conduit.

"It oscillates around this axis without passing the extreme positions, which will be indicated afterward.

"At its upper up-stream angle the ponton has an axle to which the upper wicket is fastened and around which it turns.

"We add, that the ponton is solidly built, of strong sheet-iron, and is water-tight, and a man-hole permits a workman to descend to examine the riveting.

"Besides, there is another orifice, through which a pump can be introduced to remove whatever water has penetrated through the joints.

"When the dam is raised, the upper wicket is inclined down stream at an angle of 30° with the vertical. It extends downward to 5 feet 4 inches below the level of low water, and upward to 9 feet 4 inches above the same level.

"Its dimensions are as follows:

"Length parallel to the dam	9 feet 10 inches.
"Vertical height	14 feet 2 inches.
"Height measured on the incline of 30°	16 feet 4 inches.
"Weight, all told	8,515 lbs.

"When the dam is raised the level of the pool is 6 inches, measured vertically, above the upper crest of the wicket; from this results a superficial overflow over the entire length of each wicket, and consequently over the dam.

As we have said, the wicket is fastened at the upper angle of the ponton by means of hinges, and each point moves in a plane perpendicular to the dam.

"The axis of rotation is placed at 1 foot 4 inches above the center of pressure of the water as calculated for the normal lift.

"In the upper part of each wicket there are three Papillon valves, (Fig. 69.) These valves corresponding to the shape of the wicket, are each 3 feet 1 inch high, and 2 feet wide. Their upper edges are 4 inches below the top of the wicket.

"Designed for automatic movement, they are fixed to a horizontal axis of rotation placed at 1 foot 4 inches above their lower edge.

"They are checked in their movement of rotation by a chain fastened to the valve itself, which does not permit them, while opening, to fall below a slope of 15° with the horizon.

"The retaining-chain has a counter-weight, whose use will be explained further on.

"We will further add, that the pontons have wooden borders at their ends.

"That they are separated by 8-inch braces, which serve as the upper connection of the frames and walls of the conduit, while they are fastened below to a heavy beam.

"That the line which joins the centers of two axes of rotation makes an angle of 100° with the plane of the wicket when it is up, and consequently makes an angle of 10° with the normal to this plane.

"And that two stops firmly fastened to the metal frame-work limit the play of the apparatus.

"This brief description enables us to take up the description of the movement and the calculation of the forces developed in the different positions of the dam.

"The first position to be considered is that of the dam down. (Plate 12, Fig. 68.)

"The ponton is then submerged in the conduit. The wicket lies horizontal, and covers it, and the Papillon valves are likewise horizontal.

"The river flows freely, and there is no sensible difference of level above and below the dam.

' In this condition there is no pressure, and the apparatus is only urged upward by the buoyant effort of the water displaced by the ponton; likewise its own weight is the only force which tends to press it down.

"Then the volume of water displaced is 35½ cubic feet per running foot, which corresponds to an upward pressure of 2,214 pounds. This pressure acts at a distance of ·6 feet 11 inches from the axis of rotation, and has in reference to this axis a moment of 15,254 foot-pounds.

The weight of the iron-work, wood, and appendages of the ponton is 1,462 pounds, and as this weight acts at a distance of 7 feet 4¼ inches from the axis of rotation, it gives a moment of 10,790 foot-pounds.

"To which must be added the portion of the weight of the wicket which rests upon the upper hing. It is 255 pounds, and acts at 13 feet 5 inches from the axis of rotation, giving a moment of 3,420 foot-pounds. This added to that of the ponton gives a total of 14,210 foot-pounds.

"Thus the moment of the buoyant effort exceeds that of the weight by 15,254—14,210 =1,044 foot-pounds.

"Will this excess of force be sufficient to overcome all the passive resistances of the machinery, such as friction on the axis, and on the sides, weight of the water, &c.? We do not think so.

"But if the ponton should tend to rise under this feeble impulse, a few pounds of ballast would suffice to hold it in its place.

"We may, therefore, until experiment has decided the question, retain these distributions of weights, which have the incontestable advantage of making the machinery very sensitive at the start."

A difference of level seems necessary in order to put in motion the apparatus as described. The question is how to secure this while the pass remains open.

"Two ways of overcoming this difficulty present themselves.

"In the first place, it is possible so to increase the volume displaced by the ponton as to make an upward moment sufficiently great to overcome all the resistances to motion.

"But this would lead to a very considerable lowering of the bottom of the water conduit.

"Moreover, the ascending force thus created becomes an obstacle when the dam is to be let down or is to be kept down.

"Another remedy must therefore be sought.

"It consists in borrowing the water necessary to start the apparatus from a reservoir established on the bank, which fills itself from the upper pool when the latter is created.

"Thus, water of a pressure much greater than is needed for getting under way can be obtained at a nominal cost.

"It is important to bear in mind that the conduit being already full of water, the reservoir need only provide for filling the empty space caused the movement of the pontons, and for the loss of water through the joints.

"The vacuum left in moving the ponton is 21 cubic feet per running foot, or 6,300 cubic feet for a length of 300 feet.

"If an equal volume be added for the waste through the joints, we see that a reservoir of the capacity of 13,000 cubic feet will be more than sufficient.

"This reservoir, which communicates with the upper pool, ought necessarily to be at least 10 feet higher than the lower pool.

"It will generally be filled without cost, since all that is necessary is to put the reservoir in communication with the upper pool, and to preserve the water which will thus be stored up.

"From what precedes, we believe that we may conclude that the raising of the dam will take place without difficulty."

The calculations of the forces acting on the dam at different stages are omitted. They show, however, that in low water, when the difference of level between the two pools is greatest, there will be an upward pressure of 4,363 lbs. on each of the stops that prevent the ponton from rising too high. This pressure diminishes as the water rises. These stops are placed at 13 feet 9 inches from the axis of rotation.

"Whichever of these figures [those for various differences of level] is considered, it is impossible to avoid seeing that they will naturally make the security of the stops a matter of doubt.

"It is for this reason that in the face of the lockette which looks toward the dam an opening has been made, which may be unmasked at will. By suitably arranging this opening and regulating the introduction of water into the chamber of the lockette, a less level may be substituted for the level of the upper pool, and the upward pressure on the ponton may be lessened as much as may be judged proper."

It may readily be shown by calculation that when the conduit is connected with the lower pool, the dam will fall, no matter what may be the stage in the river.

"In what precedes we have supposed that the upper wicket, as it rises, will turn of itself on its axis, resting against the suitably-rounded edge of the metallic frame.

"But it is important to examine into the conditions under which the movement can be completed.

"At the start, and before the establishment of back-water, the only force opposed to the turning of the wicket is the friction of its gudgeons in their boxes. This friction, which amounts to about 18 per cent. of the pressure, acts at the extremity of a lever-arm of 2¼ inches, and cannot successfully resist the weight of the wicket, which acts at the end of a lever-arm of 16 inches.

"The wicket, therefore, will at once begin to swing. But, as it rises, the obstacle which it opposes to the flow of the water will increase, back-water will form above, and by new pressure will give rise to new elements of resistance.

"On the other hand, the lever-arm of the resultant of the weights will diminish in consequence of the increasing inclination of the wicket to the horizon. There is, therefore, reason for dreading lest between these two groups of forces, one opposed to swinging and increasing in amount, and the other acting in the opposite direction, but decreasing, a momentary equilibrium should be established, whence might ensue a stoppage of the movement.

"The most critical moment is evidently when the upper edge of the wicket, after reaching the level of the lower pool, commences to rise out of the water. Until then the pressure acts uniformly on the upper surface of the wicket. When the wicket begins to emerge, its upper part is relatively lightened."

Calculations show that when the back-water above reaches a height of about 4 inches, the wicket will no longer have a tendency to turn.

"If, then, there were no other means of throwing the center of pressure below the axis of rotation, the movement of the wicket would not continue, unless, by the addition of suitable weights, the superiority were assured of the moments of the forces that act to revolve the wicket over the resisting moments.

"But the play of the Papillon valves comes in, and this valuable organ spontaneously causes the displacement of the centers of pressure.

"In fact, the Papillon valves, which, like others, are uniformly loaded on the upper faces, swing open, and practically lessen by 3 feet 1¼ inches the length of the wicket above the axis, which is under pressure from the upper pool.

"By this means the center of pressure is suddenly thrown below the axis of rotation, and the moment of these pressures, acting in the same direction as the weight, accelerates instead of retarding the swinging movement."

From calculations which we omit, the inventor concludes, "that the Papillon valves will swing of themselves, before the level of the water held back is raised one foot in vertical height above the upper edge of the wicket.

* * * * * * *

"In order to make sure that the valves will close, it is better to introduce a new element of action, only it is necessary that the weight, from which the additional force is obtained, should be so placed that, while aiding the valve to shut, it may not hinder it from swinging open. This result is easily obtained by fastening a ball to the last link of the holding chain. When the valve is shut it is supported by the ring to which the retaining chain is fastened. When the valve is swung open it pulls upon its upstream end, generating a moment of 1.3 foot-pounds for each pound of weight.

"It is therefore practicable, by the aid of this very simple arrangement, or by the aid of a spring, to facilitate the return of the valve, and to make it as sensitive in closing as in opening.

"Experience will very soon show the amount of additional weight to be used for this purpose.

"But we may conclude from what precedes that the valves may easily be arranged so as to swing when the level of the water rises to one foot above the top of the wicket, and to close when the water is even with the top.

"Except in case of a flood, the level of the pool will then oscillate around a mean position of 6 inches above the top of the wicket, and will not vary more than 6 inches in either direction.

"In what precedes we have investigated the movement of the whole dam, then that of the wickets, and lastly that of the valves, calculating for each the forces generated, and deducting from these calculations the practical means of providing for the proper working of the machinery under the assumed conditions.

"It appears to us, from this discussion, that the moveable dam which we have described ought to work satisfactorily, making due allowance for the slight changes which experience will indicate.

"It only remains to examine into what will happen in particular cases.

"As a rule the wicket should only move when started by man's intervention. The valves alone ought to suffice for maintaining automatically the level of the pool, when the oscillations are not too great.

"If, then, a rise of any importance should occur, the dam should be worked in time to pass the wave, by totally or partially obliterating the relief of the works."

The inventor concludes that if a sudden rise should come at night, of 6 feet, for example, the wicket will spring spontaneously, and no injurious effects will accrue. The same thing will happen if the wickets are struck by heavy floating bodies, but they will rise again after these bodies have passed by.

"Before closing this chapter we ought to call attention to a very valuable property of our dam, its power of maintaining itself in any position intermediate between the extreme ones of being entirely raised or entirely lowered.

"In fact, by following closely the description of the movement of raising, it will be seen that the ponton can only rise in proportion as the conduit is filled.

"If, then, by a suitable play of the valves the introduction of water is limited to what is strictly necessary to replace losses by leakage, the level in the conduit ceases to rise, and the upward travel of the pontons, and that of the wickets also, is arrested. The wickets will then remain stationary, oscillating feebly around the mean position where we may choose to hold them.

"It is equally practicable, in the opposite case, to limit the discharge to what is necessary to pass the water that enters through the joints of the apparatus, and when that is done the ponton will cease to descend.

"It follows from this that it is practicable to give the dam such an intermediate position as may be thought suitable to the state of the river.

"In order to secure definite ideas and to substitute figures for general formulas, we decided to assume such conditions as would make it possible to get the exact comparisons of cost which we desired.

"It is for these reasons that in what precedes we have assumed that the dam creates a lift of 9 feet 10 inches, and has an open pass of 2 feet 7 inches.

"But these dimensions are not essential, and others could easily have been taken.

"If the fall and the pass are diminished, we obtain a smaller dam, and no difficulty would arise that could throw any doubt on the good working of the reduced apparatus.

"It might, however, be asked whether, bearing in mind its necessarily high cost, it will be a useful expenditure for small lifts. This is doubtful.

"But it is equally applicable to still higher lifts, and how much may the lift be increased? This is what it is important to examine.

"The pressure of water and the weight of machinery increase rapidly with the lift, but the counter-pressure and the counter-weights increase yet more rapidly; whence it follows that the river always furnishes us more auxiliary than adverse forces, and that in this contest, in which we limit ourselves to taking command and providing the field of battle, victory ought definitely to remain with us as long as any contest is possible. And the contest will only cease to be possible when the magnitude of the forces developed becomes such that we can no longer transmit them by our machinery.

"It is, then, certain, thanks to the progress made in metallic constructions, that this transmission is possible, within very extended limits. and that dams of 13, 16, 20, and

23 feet of lift would not, as far as concerns construction, give rise to any insoluble difficulty.

"This is evident as regards the valve, the ponton, the lockette, and equally so as to the journals, which will not have to support loads at all comparable to those borne by the journals of large hydraulic wheels. In short it will be no more difficult to pass from a dam of 10-foot lift to one of 20 foot, than it was to pass from steam-engines of 300 horse-power to those of 600."

M. de Lagrené adds that he would have liked to have made some additional calculations upon the forces develeped in different positions of the Krantz Dam, but that he thought it better to wait until the Port Villez Dam could be tested, and therefore he contents himself with reproducing the inventor's description.

DAM WITH HINGED GATES—CARRO SYSTEM.

M. Carro, an engineer connected with the Marne navigation, has proposed a system of dams which, like the preceding system, obtains its motive-force from the water-course on which it is built, but which, according to the inventor, may be applied to lifts for which the Desfontaines system will not answer. The new apparatus appears to have the additional advantage of serving as a regulator, as it will lower itself little by little as the discharge of the river increases.

The following is the description given by M. Carro in a pamphlet published in 1870:

"The apparatus which we propose, (Plate 13, Figs. 71, 72, 73,) when reduced to its simplest form, comprises two gates, which are connected on top by hinges, and rest on wooden axles terminated by journals provided with rollers. The gates roll upon rails placed parallel to the thread of the stream.

"Links fastened to the lower gate, below the middle, are also fastened by a second articulation to fixed points distributed along a right line parallel to the crest of the dam, and at right angles to the current. A depression or chamber, from 1 foot 8 inches to 2 feet in depth, is prepared under the gates.

"When the latter are raised so as to form a dam they have the appearance of an isosceles triangle, (Fig. 71,) whose apex is the crest of the weir. In order to remove the obstacle which they present to the current they are made to slide, or rather to roll in opposite directions, until they lie down flat on the sole, and only make, as it were, a flooring to cover it. The two gates may therefore be considered as a single one, jointed at a fracture in the middle, which works under the pressure of the water when the dam is maneuvered.

"If we consider the gates in the position last examined, and suppose that by a special arrangement of valves, of which we will speak further on, we put the chamber which they cover in communication with the upper pool, the water introduced will exercise, by virtue of the difference of level above and below the dam, an under pressure represented by this difference of level, or, more exactly, by the living force of the current.

"The upper gate will have its lower surface at least as much pressed as its upper one. As to the lower gate, it will necessarily receive an under pressure, which will compel it to rise, so that, while the links turn around the joints at their extremities, the partly rounded axle of this gate will move on a level with the horizontal plane of the sole. The rotation will continue until there is an equilibrium between the water-pressure pushing the gate, and the reaction of the links, and of the rails on which the rollers travel, with which the ends of this axle are provided.

"To accomplish the inverse operation, it is only necessary to interrupt the communication of the gate-chamber with the upper pool and to connect it with the lower one. The water contained in this space, which is higher than the level of the lower pool, will flow off; the under pressure on the lower gate will disappear, whilst on the other hand the equilibrium on the upper gate will be destroyed, the moment of the greater force will throw the latter down on the floor, and in its movement it will drag down its down-stream partner, making it roll on the iron track. Such is the principle of the proposed machinery, on the subject of which we will now enter into detail.

"The preceding description shows that the upper gate opposes no resistance to the raising of the apparatus, since it is in equilibrium, if not even under a slight lifting pressure, due to the slope of the water between the head of the supply-aqueduct and the orifice by which it communicates with the chamber." (Note by M. De Lagrené: "This demonstration needs further development, and particularly a calculation of moments.")

"It must likewise be remarked that when the apparatus works under full pressure the upper gate only plays a passive part, and its influence is only felt at the moment of the partial or complete lowering of the system.

"If we suppose the apparatus entirely down on the sole, then the upper gate opposes the spontaneous rising of the lower one, and but for it the latter would yield to the action of the current on account of the position of its axis of rotation under the middle of its length.

"This position of the axis in the middle of the gate explains how the latter rises when it is under the influence of the under pressure.

"In fact let C (Fig. 74, Plate 13) be the position of the center of under pressure on the lower gate, being at its middle when the latter is completely immersed. If this point C is on the up-stream side of the joint D of the link, the force of under pressure R will be decomposed into two other parallel but opposing forces P and Q respectively, applied to the points D and B. The force P will determine the rotation of the link around the point K, while the force Q pressing the lower end of the gate on its railroad, will compel it to rise.

"We have therefore chosen for the point of attachment of the links a point whose position is always on the down-stream side of that taken by the center of the under pressure in the different phases of the ascending movement of the gates. By supposing the chamber constantly full of water under the pressure from above, we know that the point of application of the under pressure always lies between the third and the middle of the lower gate, the first position corresponding to the extreme case where there is no counter-pressure of water, and the second to that in which this gate is completely submerged below the level of the lower pool. If, then, we place the joint D of the link at one-third of the gate from its foot, we will be sure that the center of under pressure will always be above this axis, and that it will only coincide with it in the case when the sole below is uncovered.

"The last-mentioned position is the one which must be chosen for a weir whose permanent part will not always be submerged by the water of the lower pool.

"In a navigable pass, where is always a counter-pressure, there is no inconvenience in placing the point of attachment of the link even at the center of the under pressure, always keeping in mind the counter-pressure of the water below.

"In the machinery in question, the pressure is reduced to an effort of extension, which is met by ties or links, whose number may be multiplied at discretion, but two will evidently suffice for each lower gate.

"These links may be attached to a sill fixed on the sole, whose tendency to be raised or torn out can easily be counteracted.

"To accomplish the same object we might have recourse to iron rails extending across the gate-chambers, and resisting the pull of the links by utilizing the weights of the masonry of the side-walls, which by this means are solidly connected. This second arrangement is the one shown on Plate 13.

"When the two twin gates lie on the sole it is evident that however small be the play left between the upper one and the surface of the paving, the current may penetrate within and raise it. It would not then be practicable to keep it under water if this tendency were not met by a specal arrangement.

"This tendency to rise may be overcome by replacing the ordinary rails by double-T irons, forming channels in which the journals at the end of the axles can slide.

"However, we have chosen another means, which offers us more security against the introduction of sand under the gate, which may, in certain cases, paralyze the movements.

"In the arrangement finally adopted the upper gate is composed of a square frame, which is only partly covered, all the lower part being left open. A third gate, which we will call the screen, is placed above, which is fastened by hinges to a sill fixed on the sole. This screen falls down stream, covering the empty space left in the lower part of the upper gate; rollers on its upper cross-piece facilitate the sliding on this upper gate, and the latter raises the screen as it comes up in the upward movement of the crest of the dam.

"The introduction of this new organ does not at all change the working of the apparatus. The water, which penetrates with its living force into the gate-chamber, exercises a pressure on the lower gate, which it compels to move, whilst the upper gate and its screen find themselves in a manner inclosed in still water, being pressed equally on their two faces, and consequently opposing no resistance to the movement derived from the lower gate.

"A dam, or a sluice, is provided with a series of couples of twin gates like those which we have briefly described.

"All the lower gates, which form one part of the movable apparatus of the dam, are simultaneously subjected to the influence of the same under-pressure. It nevertheless may happen that the friction of a hinge, resulting from insufficient play in the articulation, may make a couple of gates a little more sluggish in moving than others; or, it may even be granted that the interior current, which is created at the moment the supply-valves are opened, will not make the under-pressure instantaneously uniform under all the pairs of gates, and that they might have a tendency to rise successively.

"If these pairs of twin gates were independent of each other, the beginning of their rising under the hydraulic pressure might possibly not be simultaneous throughout the length of the dam; there would be reason to fear that one of them in rising would separate from the neighboring pair, an opening would then be formed between the two, which would allow the inclosed water to escape, and by destroying the under pressure would cause the maneuver to fail. But it is easy to prevent this lack of coincidence in the different phases of the movement.

"The conditions of equilibrium under which the gates are placed are, as we have said, sensibly the same, and in practice can differ but slightly. If, then, we suppose that we connect by transverse beams the gates that fall the same way, they will be stiffened, and will simultaneously obey the forces which tend to move them.

"Is there any danger that the axle of the two hinges which connect on top the upper and lower gates of the proposed system might not be perfectly rectilinear, and that in consequence passive resistance might result of such a character as to interfere with maneuvering? We have taken the precaution to give to these hinges a single axle of rotation, so that each pair of gates, considered separately, cannot give rise to such an apprehension.

"As to the straightness of the line formed by the series of independent axles, there is no reason to expect that it can become so crooked as to prevent the simultaneous movement of the shutters. The transverse beam which keeps them stiff is fastened by bolts in the spaces which separate the neighboring pairs. A certain amount of play results,' which permits these gates to have a slight transverse displacement, analogous to that of a car in the space between the rails of the road on which it travels.

"In addition, we can attain the same end by suppressing the transverse beam, which binds together the different couples of a bay, and giving a single axle of rotation to the upper joints of all the links, thus securing the same rigidity.

"The play left between the gates of two adjoining pairs may be as limited as possible, and the direction given by the rails to the movement of these gates reduces its variation to narrow limits. However, it is worth while to remark that the vacant spaces between the upper gates will always act in the opposite way to those of the lower gates, and that if one set tends to interfere with maneuvering the other will assist it.

"Two water-conduits at the ends of the weir, or of the pass, are unnecessary, as a single one will undoubtedly suffice for the working of the machinery. The second one would probably only be indispensable where the river to be canalized had considerable width, which would cause a longer length of weir than is usual. However, if we can avoid making a second conduit, we think that it would be well to reserve in the body of the opposite bounding-wall an emptying-conduit, in order to have the means of creating in the chamber the scour of water necessary for cleansing it.

"If, in a long dam, there were reason to dread the effect of warping, it would only be necessary to divide the dam into several bays, formed of gates firmly fastened together. Small and narrow piers, separating the different groups of gates, and pierced to provide communications between the gate-chambers, would act as partitions, and make them independent.

"The division of the dam into several bays would have the additional advantage that, in the event of future repairs, it would assist in the establishment of coffer-dams to isolate the bay where work was to be done. Repairs could be made while the dam was working, since the two segments could be fed respectively from the two ends.

"One of the characteristics of the proposed apparatus is, that it permits any desired change in the height of the dam.

"If a flood should make its appearance, it would be easy to partly lower the gates, and thus retain the water of the upper pool at a sensibly constant level until the moment came to make the relief of the movable part disappear entirely.

"In fact, the system of valving, first thought of in order to make and break alternately the communication between the gate-chamber and the upper and lower pools, consists of two valves, placed in the longitudinal aqueduct for supplying water, one above and the other below the transverse opening. Then, if the supply-valve be slightly lowered, and the discharge-valve correspondingly raised, the water in the space between them will soon, in consequence of this maneuver, take a level intermediate between the upper and lower pools, the interior pressure will diminish, and the upper gates will push down their partners until a new state of equilibrium is produced, and their movement ceases.

"A few turns of a wrench will then suffice to enable one to vary at will the position of the crest of the weir.

"We have seen that the two valves always work in contrary directions, that is, when one rises the other ought to lower; and that the play of the machinery depends rather on the relative than on the absolute size of the openings. It follows from this that by connecting the rods of the two valves by a balance-beam, as M. Desfontaines has done, we can simultaneously cause the double maneuver by means of a single screw, moved by hand.

"However, we think that in the case in question it is preferable to use another kind of valving, which has the property of being automatic, and better performs the duty of regulating the level of the pool.

"A weir, and especially a navigable pass, constructed according to the system which has just been described, will have the advantage of not causing at the moment of opening a scour dangerous to the preservation of the lower part of the sole. The crest of the movable apparatus, by gradually lowering along its whole length, will cause a less dangérous superficial current."

We see from this discussion that the proposed system is distinguished by its simple and ingenious arrangements, whose combination appears rational. M. Carro besides introduced, in 1872, some improvements on the first plan, which has just been described.

For fear that a variation of pressure in the lower conduit might cause a warping in the girders, which connected together the different pairs of gates, he modified this method of consolidation. The method which he finally adopted will, according to him, permit the use of sufficiently long bays, even without the intermediate piers to act as partitions. Besides, in the new arrangement the screen which was to rest on the upper gate is suppressed, and replaced by a simple iron plate, a sort of permanent joint-cover, like that which covers and holds the end of the breech of a Krantz wicket when it is down. (Plate 12, Fig. 68.)

But, as I have already said, it is only by trial that the merit of any new system whatever of movable dam can be determined.

Reference has been made in the above to the automatic valves invented by M. Carro, in order to regulate the level of the upper pool. These valves are described by M. De Lagrené in a preceding chapter, from which the following is taken:

SELF-REGULATING TWIN WICKETS.

I have already shown that a wicket which turns around a horizontal axis can be centered in such a way as to swing when the pool is slightly higher than a given level, but that it will not lift itself up until after a considerable lowering of the pool below this level. Such a wicket is not automatic.

But it is possible to couple two wickets together in such a way that the combination shall have this property.

Suppose, for example, a pier or an abutment, pierced by an aqueduct parallel to the axis of the stream, and in this aqueduct two wickets suspended, each with a horizontal axis, but so connected together that when one is vertical the other is horizontal. These wickets are centered in such a way that their center of gravity is nearly in each axis of rotation. The property which one has of swinging can be utilized to set up the other, and if in the pier or abutment the opening of a transverse aqueduct should lie between the two, it is evident that this aqueduct will be opened or closed automatically by very slight oscillations of the pool above or below a given level.

Such is the principle of the self-regulating twin wickets. I will now show two applications of this principle, which will make it more readily understood.

The first is due to M. Carro, and the second I easily deduced.

The transverse aqueduct, which is to be opened or shut in accordance with the oscillations of the upper level, may have different functions.

For example, it may form the head of the supply-conduit, which leads the motive-water to the movable members of a dam. Examples of this will be found in the following chapters. [Already given.]

In this case the water ought to enter the transverse aqueduct whenever the upper pool falls below a given level. The lower wicket ought then to be shut, and the upper wicket to be on the swing, when the water is low.

It may also form the head of a waste-weir, designed to carry off in any direction the superfluous water from the upper pool. In this case the water should enter the transverse aqueduct when the upper level is raised above the normal level, and in consequence the lower wicket is the one to be closed, and the upper wicket to be opened during high water.

There are therefore two distinct methods of combination, according to which one of these two ends is to be attained.

I will begin by examining the first case, that in which the transverse aqueduct of the pier, or the abutment, conducts the water which works a movable dam.

Plate 14, Figs. 77 and 78, shows the arrangement invented by M. Carro, and the following is his way of explaining the automatic movements of the wickets:

Suppose a wicket, A B, (Plate 13, Fig. 75.) standing vertically against a sill on its lower side, and able to turn around an axis of rotation, I, in such a way that its chase falls in the direction of the current. The pressure which it supports under a fall, A P, is represented by the surface of the polygon, A B C D, and the center of pressure by the projection upon the wicket of the center of gravity of this polygon. In low-water the center of pressure is below the axis of rotation, and the wicket remains upright. If a flood comes, the center of gravity of the figure representing the pressure rises with the flood, and when it has passed the level of the axis of rotation the wicket swings.

On the other hand, let us consider (Plate 13, Fig. 76) a wicket resting against a sill placed on the upper side of its breech in such a way that it can only turn in the opposite direction to the preceding; the opposite conditions will prevail, opening during low-water, and closing during rises.

Then let us suppose that these wickets are united by a connecting-rod of such a length that the vertical position of one corresponds to the horizontal position of the other. During the period of low-water the lower wicket is naturally closed, and it keeps the upper one open. The motive-water then enters the transverse aqueduct, and assures the working of the movable parts that make a dam.

The river still rising, the center of pressure rises above the axis of rotation of the lower wicket and makes it swing, and its movement compels the closing of the upper wicket. The transverse aqueduct then no longer receives the water from above, and the movable parts, deprived of their motor, fall down on the sole. If the river subsequently falls, the center of pressure of the upper wicket descends below the axis of rotation, and by compelling it to swing, and in consequence to close the lower wicket, the motive-water is again sent to the dam, and the latter rises.

It is possible so to arrange the axes of rotation of the two wickets that the centers of pressure will coincide with them when the natural level of the river rises to a given height; for example, when this level below the dam reaches the minimum depth for navigation. The discharge of the river, corresponding to this minimum level, is known; from it is deduced the depth of the overflow, and consequently the level above which answers to this discharge when the dam is up. The shape of the polygon representing the pressure is then determined, and it is only necessary to find its center of gravity to know the height of the axes of rotation of the wickets.

At a slightly higher level in the upper pool the lower wicket will swing, and will set up the upper wicket, and, in consequence, the flow of the motive-water will be stopped.

At a slightly lower level in the upper pool the upper wicket will swing, setting up the lower wicket, and sending the motive-water through the transverse aqueduct.

The automatic working of the dam is then assured by means of the twin wickets.

M. Carro expresses the opinion that the opening of the wickets would not take place suddenly, so as to cause the river to pass too rapidly from one state to another more or less different. He says that the transition will undoubtedly take place by scarcely preceptible degrees, corresponding to a partial working of the wickets, and giving, in the transverse aqueduct, the effect of a level intermediate between those above and below. It can readily be understood that when the upper wicket is partly set up, its center of pressure will soon fall below its axis of rotation; it will then react against the pull of the lower wicket, and will hinder the latter from swinging completely, holding it at an inclination corresponding to its own.

In certain circumstances it might be useful to maneuver the wickets without waiting for their spontaneous movement. This can be done by fastening to the lower part of the lower wicket (Plate 14, Fig. 77) a chain which is wound around a drum. A second chain is likewise fastened to the lower end of the upper wicket and wound on the same drum, but in a contrary direction to the first chain, so that one unwinds as the other winds. The wickets may then be held wherever desired by simply turning the drum.

Fig. 79. Plate 14, represents the arrangement of twin wickets which may be used to carry off the surplus of a pool. The explanations already given, and an inspection of the figure, are enough to indicate how this pool will regulate itself spontaneously. The transverse aqueduct either empties the surplus into the lower pool, or into ditches for use in agriculture or in manufacturing.

Twin wickets cannot be used to form a dam in the bed of a navigable river, since they cannot get out of the way at any given moment, but we see that they can render services similar to those obtained from oscillating wickets.

DAMS WITH SHUTTERS WORKED BY HYDRAULIC JACKS—GIRARD SYSTEM.

I explained in Chapter VII that Thénard shutters, having their axes of rotation on the sole, present so great a resistance to raising as to be inapplicable to high lifts as long as only the ordinary mechanism of movable dams is used.

M. Girard, a civil engineer, who died in 1871, has found an easy method of working these shutters by pushing them by means of hydraulic jacks, which, at will, by means of a cock, may be put in communication with an accumulator on the bank.

This is the general idea of the system, whose trial was authorized by an official order of June 23, 1870. The point selected was on the Yonne, at the weir of the Ile-Brulée Dam, which is situated a little more than a mile below Auxerre, and has a normal fall of 6 feet.

The following is the description of the movable parts, taken from M. Girard's project for a high dam: (Plate 14.)

Each shutter is composed of three pieces of wrought iron of this shape, I, fastened at bottom to an axle which forms a hinge throughout its length. This hinge turns in a cast-iron hollow quoin, made fast to the sole.

The I-irons are covered on their down-stream faces by a plate of sheet-iron, and on their up-stream faces by oak timbers.

A shutter is 11½ feet in length, measured in a plane normal to the axis of rotation, and commencing at this axis. Its vertical projection, when it is up, is 10½ feet; its horizontal width is 13 feet 1¼ inches.

A shutter, when up, has a batter of four-tenths. The space between two consecutive shutters is 1¾ inches.

Below each shutter a cast-iron cylinder is fastened to the sole on a slope of about 10°; this cylinder, called by M. Girard *corps de presse*, receives a piston, one foot in diameter, on whose outer end is a cast-iron cross-head, which is constrained to slide in three cast-iron guides, designed to secure its rectilinear motion. These guides are fastened to the sole, and are parallel to the prolongation of the axis of the cylinder of the jack.

Upon the cross-head of the piston are fastened three bars, which act as props to the shutter; each of these bars is fastened by a wrought-iron fork to one of the T-irons of the shutter at its middle.

Each cylinder receives at its lower end a gas-pipe of one inch interior diameter, whose other end terminates in the accumulator.

A three-channel cock, placed near the latter, permits either the introduction of water from the accumulator into the cylinder of the jack, or the removal of the water in the cylinder, or the establishment of a direct communication between the cylinder and the pump which supplies the accumulator.

Each shutter having its own jack, supply-tube, and regulating-cock, can at will be worked by itself, or in conjunction with the others.

The motive-water is obtained either from the upper pool or from a tank, by means of a double-acting pump set in motion by a turbine, which receives its impulse from the fall at the dam.

The turbine, the tank, the force-pump, and the accumulator are placed in a little building constructed on the abutment of the weir.

The use of a turbine presupposes the existence of a fall.

At the Ile-Brulée Dam, as the weir is not shut until after the navigable pass, which is provided with Chanoine wickets, is closed, the reduction of section which results from the closing necessarily produces a difference of level between the water above the dam and that below it.

It is only necessary that this difference of level should be sufficient to enable the turbine to do its necessary work. I will take up this matter directly.

In case there is no fall, as if, for example, all the dam were provided with Girard shuttles, and the sill were not raised above the bottom, it would be necessary to resort to a steam-engine to work the supply-pump. Such was M. Girard's first idea, but having observed that at the Ile-Brulée Dam the preliminary closing of the pass would cause a fall of at least 16 inches, the turbine was calculated so as to produce with this fall the useful work necessary for raising the shutters, and in this first application of the system the idea of a steam-engine was abandoned.

As the pump can act directly on the cylinders of the hydraulic jacks, the accumulator is not indispensable, but it is useful, in that it serves to equalize the work of the pump, and also in that it permits more prompt maneuvering, as there is always pressure in reserve even before the closing of the pass is begun.

This description is sufficient to explain the method of opening or of closing the weir, a maneuver which is reduced to turning to a certain point each one of the cocks of the supply-pipes.

Any shutter whatever may be stopped at any moment whatever in its rise or fall by a simple turn of the corresponding cock.

I have already pointed out the advantages resulting from this, both in moderating the scouring force of the cataract and in providing for a small rise, precisely the outlet which it needs, without sensibly changing the upper level.

It is important that the piston of each jack should be prevented from acquiring too great a velocity, even though there may be a great excess of power. This result is obtained by giving the cock an opening of such a size that the water in passing through it loses a part of its living force.

Suppose, for example, that the piston has a velocity of 4 inches per second, a velocity which cannot cause an injurious shock when it is stopped; suppose, besides, that the pressure in the accumulator is of twenty atmospheres, the velocity of exit of the water will be $\sqrt{2g \times 20 \times 34} = 209$ feet; and all that is necessary in order that the piston speed may not exceed 4 inches per second is that its section should bear the relation to the opening in the cock of $\frac{209}{0.33} = 627$.

With this speed the travel of the piston is 5 feet, and the raising or lowering of the whole weir will take place in 15 seconds. Making due allowance for losses of pressure, we can still feel sure that each complete maneuver will take place in less than a minute, whatever be the length dammed.

The cocks can readily be turned by a float, and consequently they can at will be passive or automatic.

The system which has just been described has several remarkable properties, namely:

Rapid and easy maneuvers without shock.

Great reduction in leakage, on account of the less number of spaces between shutters.

Possibility of application to great lifts and lengths.

But there are also inconveniences.

The principal objection to the system arises from the effect of freezing on the supply-pipes, and on the cylinders of the jacks.

If we endeavor to avoid these effects, by placing the machines at a considerable depth below low water, it becomes very difficult to repair them. Besides, the smallest leakage in apparatus, which is almost constantly subject to heavy pressure, will stop its workings.

M. Girard proposed filling the pipes and the cylinders with a mixture of water and alcohol, which only freezes at a very low temperature. This water was to be collected in a waste-well when it came out of the cylinders, when the dam was lowered, and then repumped into the accumulator; but this expedient did not appear practical, and it was considered sufficient, at the Isle-Brulée weir, to place the communicating pipes 5 feet below the lowest water, after the whole apparatus had been subjected to a proof-pressure of at least thirty atmospheres.

The pipes are placed in a masonry conduit prepared in the sole, and covered by a cast-iron plate.

To repair, while under pressure, a shutter which no longer works, a screen would probably be placed in front of this shutter, which would support itself on the neighboring shutters; the one to be repaired, being thus relieved, might be removed; but unfastening under water and replacing the cylinder and its pipe are rather delicate operations, and are very rarely admissible. Use will teach whether this is too great a difficulty in practice.

The absolute rigidity of each shutter has also been made an objection to this system. If a floating body strikes, it will not yield, and violent strains are produced both on the fastenings and on the organs themselves; as a matter of fact, there is the same trouble with a needle-dam.

On the other hand, I have seen a raft of timber drift against the navigable pass of the Evry dam, and break through, making the wickets swing, but causing no damage.

In addition, there is reason to fear that sand may work in between the slides and the crosss-head of each piston, and may give rise to so much friction as to cause too great wear on the rubbing surfaces.

Lastly, when the operation of raising is begun, the prop makes a very acute angle with the shutter, and consequently the normal component, which alone performs useful work, is at first only a feeble fraction of the force exerted on the piston. It also follows that the component in the direction of the shutter is large, and produces friction and compression on the axle and its collars, which cannot be neglected.

The author's calculations on the moments of the developed forces are omitted.

The dimensions of the force-pump, which in case of need must act directly on the hydraulic jacks, without the use of the accumulator, depend on the time allowed for raising.

If we suppose, for example, that the weir should be raised in the space of ten minutes, and if the travel of each piston is 5 feet 7 inches, the volume generated is 4.24 cubic feet, and for the seven shutters 29¾ cubic feet. This is equivalent to a continuous discharge of 2.97 cubic feet per minute. The pump and the turbine which puts it in motion under a known fall of 16 inches, for example, as at the Ile-Brulée Dam, should be so arranged as to produce this discharge of 2.97 cubic feet per minute under the pressure which corresponds to the fall of 16 inches.

In addition, it is necessary that, after the fall increases, the pump and the turbine should still be able to produce this same discharge under the increased pressure which will result.

As I have said before, the navigable pass of the Ile-Brulée Dam is provided with Chanoine wickets. Its weir only is provided with Girard shutters, whose dimensions are smaller than those represented on Plate 15, but whose general arrangement is the same.

Each shutter is 11½ feet wide and 6½ feet long, measured along its slope and in a plane normal to the axis of rotation. The total batter of a shutter when up is 16 inches, which corresponds to an angle with the vertical of nearly 12°.

The weir is 82 feet long and has seven shutters, each interval being 1¾ inches.

Two of these seven shutters have Papillon valves in their chases.

The upper pool is at the reference 314.72 above the sea; the lower pool is at the reference 308.65; whence results a fall of 6.07 feet.

The crown of the masonry which forms the permanent part is at the reference 308.15; that is, at half a foot below the level of the lower pool. The axis of rotation fastened on this crown is at 3 inches below the level of the lower pool.

A shutter, with all the iron-work, weighs 2,552 pounds.

A piston, with its cross-head, weighs 3,938 pounds.

It is conceded that the pressure in the reservoir should not exceed 25 atmospheres.

The administration, contrary to its general practice, contracted with the inventor, M. Girard, for the shutters of the Ile-Brulée weir.

The sum allowed for furnishing and setting the movable apparatus and the dependent mechanisms was 44,000 francs, ($8,360.) This would be 537 francs ($102) per running foot.

In concluding this description it should be stated that M. Cambuzat, in his report on the navigation of the Yonne and the Upper Seine, from which we have already quoted freely, states, in regard to the Girard shutters, that they work well, but that they are costly, and that a needle-dam is preferable.

As we here end our quotations from foreign reports, it is proper to state that all the measures and calculations which have been quoted from the French are given in the originals in terms of the French metrical system. They have all been transformed into English measures, as it was believed that the usefulness of this report would have been seriously impaired if a unit of measure had been used which did not immediately convey definite ideas of dimension to American engineers.

SUMMARY AND CONCLUSIONS OF THE BOARD.

We have thus far given drawings and descriptions of all the methods of which we could learn that have been used up to the present time for the management of hydraulic gates or movable dams. The most serious difficulty in applying any of these systems to the Ohio River arises from the severity of our winters and the great masses of ice that must be provided for. In order to permit these heavy masses to pass freely, it is indispensable that in the plan adopted there should be no projecting mechanism that could possibly be injured when the pass is open; in other words, the sides and bottom of the pass should then be as smooth as those of an open cut. An approximation to this condition is an absolute necessity.

Leaving temporarily out of consideration the question of the lengths or heights of passes and weirs, we will first discuss the subject of apparatus.

The following are the methods thus far described:

1. "The bear-trap," Plate 1, Figs. 1, 2, 3.
2. The wicket used on the Riom, Plate 1, Figs. 4, 5, 6, 7.
3. Thénard shutters, Plate 1, Figs. 8, 9, 10, 11, 12.
4. Thénard shutters, as modified by Fouracres, Plate 4, Figs. 30, 31, 32, 33.
5. Poirée needle-dam, Plate 2, Figs. 13, 14, 15, 16, 17, 18.
6. Combination of Poirée dam and Thénard shutters, Plate 3, Figs. 25, 26, 27, 28, 20.
7. Chanoine wickets, Plates 5, 6, 7, Figs. 37, 38, 39, 40, 41, 42, 43, 44, 45.
8. Desfontaines wickets, Plates 8, 9, Figs. 46, 47, 48, 49, 50, 51.
9. Modified Poirée needle-dam, Plate 10, Figs. 54, 55, 56, 57, 58.
10. Cuvinot drum-wickets, Plate 11, Figs. 63, 64, 65, 66.
11. Krantz wickets with ponton, Plate 12, Figs. 67, 68, 69, 70.
12. Carro gates—improved "bear-trap"—Plate 13, Figs. 71, 72, 73.
13. Girard shutters, Plate 15, Figs. 80, 81, 82, 83, 84, 85, 86.

The objections to the "bear-trap" gates have been given at length by M. De Lagrené, and need not be repeated here. The fact that this system has been in use in France for many years to provide artificial waves for lumbering, and yet has not been adopted on the larger rivers, is sufficient to condemn it. If such a combination were used at all, it would probably take the form of the Carro modification, and therefore we need not spend time on the prototype.

Mr. H. Werner, C. E., proposed a number of "bear-trap" gates of ordinary width, giving each pair separate inlet and outlet pipes. As these gates were to be raised in succession, it was necessary to retain the water under each pair by closing each end of the space under them. For this purpose he designed solid frames of triangular shape, which were to be lifted by the main gates, rising at right angles to them, and closing each end of the space under them. The joints between the upper main gates were to be closed by narrow aprons, resting on and raised by them.

This method of construction was tested on a large model, but did not give satisfactory results. There was no trouble in raising the gates, but they could not be lowered except by hand. The difficulty seemed to arise from the side gates refusing to fall after the water was let out. The friction between them and the main gates was such as to hold them fast. This might have been expected, since even in the ordinary "bear-trap" there is difficulty in lowering the gates unless the angle between them is very obtuse.

The second method, that in use on the Riom, is manifestly only designed for small lifts and for rivers not incumbered by ice or drift. It is evidently so much inferior to some of the others that no time need be spent in discussing it.

The third, fourth, and sixth methods, two of which differ only in minor details, the third being a combination of the shutter with another system, may be discussed together. The great difficulty of raising high Thénard shutters has been mentioned in the previous discussions, and besides this, the first two methods, or the Thénard shutters proper, seem to be very objectionable in a river which carries much ice or drift. The third method, which uses but one shutter, and has a Poirée dam in addition, seems to have a superfluity of apparatus. The only apparent reason for the combination is to secure rapidity of opening by using the dam as a screen behind which to raise the shutters, and subsequently, after the dam has been removed, to drop the shutters by a tripping-rod. In view of the various devices already described for promptly opening a needle-dam, it seems unnecessary to have anything else where it is used, and therefore we are of the opinion that all the methods using the ordinary Thénard shutters should be rejected.

Of the systems that are left for examination, those of Poirée and Chanoine are in very general use. Desfontaines drum-wickets seem to be used only on weirs in the Marne. Girard shutters are used on the weir of a single dam on the Yonne; the Krantz system is in process of trial; and the Cuvinot and Carro systems exist only on paper.

The first question to be settled is the general arrangement of the locks and dams that should be recommended for use on the Ohio. The French system has a pass whose sole is level with the natural bottom of the river, and a weir whose permanent part is somewhat higher. When the pass is open, and the weir-wickets are down, the river is almost in its natural condition, but there will be an increase of velocity through the pass over the velocity that existed before the construction of the dam, the amount of which will depend upon the height and arrangement of the weir. The system which the board had in view was to build ordinary slack-water dams, and to make openings in these, connected with an inclined plane below, so that coal-fleets could be passed through the openings and down the inclined pass into the lower pool. This system was naturally suggested by the existing slack-water system on the Monongahela.

Comparing it with the French systems, assuming equal lifts at the dams, we find that the difference is that, on our plan, the weir is permanent up to the level of the pool, and the sole of the navigation-pass is about half way between the low-water line and the surface of the pool. Both weir and pass are therefore higher than is the practice in France.

Assuming, for the present, that the general combination indicated is an advantageous one, we will give a description of the various styles of gates that were examined, and, after describing the one which in our judgment seemed most suitable, will resume the comparison with the French methods.

Assuming a dam with a lift in low-water of 8 feet, as is the case with the lower dams on the Monongahela, we proposed to cut down a portion of this for a width of 200 feet, more or less, and a depth of 4 feet, and to provide the passage thus made with easily-worked apparatus for opening and closing at will. We also proposed constructing below this cut an inclined plane of slight declivity, which would form a pass into the lower pool. It should be stated that when we commenced investigating this subject we were ignorant of the great progress that had been made in it by modern French engineers, as almost the only record of their work is the *Annales des Ponts et Chaussées*, a publication which is seldom to be found in American libraries. The copies from which the translations were made were borrowed from the library of the Headquarters of the Corps of Engineers. M. De Lagrené's work is just published, and was only received during the present month.

The following plans were especially examined by the board, the majority of them being tested by models:

Mr. S. Petitdidier, C. E., proposed the system shown in section and elevation in Plate 16, Fig. 87. It consisted of a solid dam of wood, three feet wide and six feet deep, thoroughly bolted and stiffened with iron, which moved up and down, in a narrow chamber with vertical sides, under the action of heavy counter-weights at each extremity. Friction-rollers on each side of the vertical chamber facilitated the movement. The counter-weights were hung at such a height that when the water rose they were partly submerged, and their loss of weight caused the dam to descend into the chamber, and to gradually open the pass. The counter-weights were protected from floods by heavy crib-work, and automatic signals were designed to indicate, both by day and night, whether the pass was entirely or only partly open. The designer claimed that this system would work automatically. The model did not sustain his views, on account of the friction of all the parts, and the whole system was open to the objection that it would only work in floods, and could not be maneuvered without complicated mechanism and a considerable expenditure of work, at a time when there might be water enough to let fleets through, and yet not sufficient to permit the pass to remain open for any length of time.

Captain J. A. Wood, of Pittsburgh, suggested a modification of the "bear-trap." He proposed to hinge the two gates together at top, and to maneuver them by chains wound around an axle under the gates, to which motion should be given by steam or water power. The upper gate turned on an axle fastened to the floor of the pass, and the axis of the lower gate was fastened to an apron at its foot, which could move horizontally in grooves on the platform of the pass. This apron was so fastened to the platform that it could not rise. By drawing it up-stream it caused the gates to rise, and they were lowered by reversing the motion until the two gates were laid down on the platform, and the passage was left open. The gates could not be lowered into a horizontal position, as in that case it would be impossible to raise them, since any force applied to the apron would be directly transmitted to the axis of the upper gate.

No arrangement was made for admitting water under the gates, and consequently the motive-power had to lift the entire body of water resting on the gates. On this account the greatest power would be needed at the commencement of maneuvering, but at this time the lever-arm of the force would be least, and it would be acting at the greatest disadvantage. For these reasons the board did not deem it necessary to experiment on Captain Wood's system, but contented themselves with an examination of his model.

There is a remarkable similarity between the gates of Captain Wood and those designed by M. Carro. In both cases the twin gates are hinged to each other, and in each case the lower end of the lower gate is kept down on an iron track. Captain Wood, however, uses no links, and entirely overlooks the advantage of utilizing the natural water-pressure to lift his gates. On this account he would require such enormous extraneous force that his system would be impracticable for any considerable width of opening.

The Hon. F. R. Brunot, of Pittsburgh, exhibited to the board a small model of a floating hydraulic gate, which seems to meet the requirements of the case. Mr. Brunot only presented the model, leaving the completion of the details necessary to put it in practice to be elaborated by us. His system is shown, in section, on Plate 17, Figs. 90, 91, 92. It consists substantially of a hollow caisson or ponton of the length of the desired opening, (see Fig. 92,) and of suitable width and depth. A chamber is excavated in the dam at the place chosen for the gate, and when the latter is in place and lowered, the top of the caisson is even with the floor of the pass, and the passage is free. The up-stream edge of the top of the gate is securely hinged to the up-stream edge of the gate-chamber.

Two methods of maneuvering the gate were proposed by the inventor. The first method was to make a connection between the chamber and the pool above the dam, so that the hydrostatic pressure of the upper level might raise the gate. It could only rise in an inclined position, as the upper edge would be held down by the hinges. To lower the gate the connection with the upper pool would be closed and that with the lower one opened, and the gate would fall on the removal of the water-pressure. The service of the gate would be simple and inexpensive, as one man only would be required, and his work would be limited to opening and closing valves. One objection to this method of working is that a certain amount of play is necessary between the gate and the lower side of the chamber in order to prevent danger from jamming. The width of this opening could hardly be less than 2 inches, and this width into the length of the opening (200 feet) would give a total opening of 33⅓ square feet. In order, therefore, to retain within the chamber the pressure of the upper pool, it would be necessary to have a channel of communication with it of a greater sectional area than 33⅓ square feet. As this pressure would have to be kept up during the season of low water, there would ensue such an expenditure of water that, in many localities, the gate could not be used. On the Monongahela

hela, where the first pass with hydraulic gate should be built, the flow during summer is often insufficient to supply the lockage.

Another objection to this method is that it will oftentimes be necessary to lower the gate and open the pass when the water in the lower pool is even with the top of the chamber. In this case our experiments indicated that the water-pressure on top of the gate would not suffice to make it fall.

The other method suggested by Mr. Brunot is to fill the gate with water when the chute is to be opened, and to pump the water out when it is to be closed. This will, undoubtedly, secure the desired result beyond any possibility of failure, no matter what may be the difference of level between the two pools, and this is the method which we recommend. The power necessary to do the pumping can always be had from the fall at the dam, and a turbine-wheel in a well in the abutment would be the natural method of applying it.

There is a danger that sediment may enter the chamber of the Brunot gate through the opening left for play, and also that sticks and stones may get fast in it and interfere with the movement of the gate. For this reason, and in order to secure a tighter chamber, we thought that the system shown in section in Figs. 88 and 89, on Plate 16, would be better. In this the Brunot gate is hinged to the lower edge of the chamber, and a heavy wooden apron rests on it, which is hinged above the chamber to the platform of the chute. This system gives ample play to the gate, and almost entirely obviates any trouble from sediment and from floating bodies or stones rolled along by the current. It is, in fact, a combination of the Brunot and the "bear-trap" systems. There is also a very striking similarity to the main part of the Krantz system, the chief difference being in the method of fastening the apron. It is an apparent objection to the Krantz system that the cavity prepared for the lower end of the apron might be filled with sediment or obstructed by stones and gravel rolled along the bed of the stream. We finally, however, concluded to abandon this combination, because we found that by putting a shoulder on the lower edge of the Brunot gate, as shown in Figs. 90 and 91, we could retain sufficient play, and yet make a tight fit against the chamber-wall, and because in elaborating the details of filling and opening the gate in the combined system, we found many practical difficulties that do not exist in the Brunot system proper. In the combination of the two systems the apron would have to be very wide, for the same reason as in the "bear-trap" proper, and it would be open to the same objections.

Col. P. J. Schopp, C. E., suggested what he termed a "triangular caisson dam," but as it consisted substantially of a number of Brunot caissons of triangular cross-section, each provided with an independent chamber, and maneuvered in succession, we did not deem it necessary to test the plan in a model. He proposed working his gates entirely by changing the pressure of the water under them, but, as we have previously stated, our experiments on models indicated that this method would sometimes fail, and the application of the pumping system to a number of caissons would increase the difficulties of working, without corresponding advantages.

The system now in use on the Yonne and Seine has the advantage of being the gradual growth of long years of study and experiment, and will, undoubtedly, at least on the Upper Ohio, radically improve the navigation. The question before us, therefore, is whether this system is the best that can be devised for such navigation as is used on the

Ohio River, or whether we cannot obtain a method more suited to our wants.

As can be seen from the discussion, and from the tables which have been given, the French system gives 5 feet in depth at the head of each pool, and the lifts, or differences of level between the pools, vary on the Seine from 4 feet 5 inches, at the Melun Dam, to 9 feet 10 inches at Port-à l'Anglais. The latter lift is exceptionally great, on account of the wish to avoid constructing a dam within the limits of Paris, the next greatest lift being 6 feet 1 inch, at Ablon.

At the La Madeleine Dam, which may be taken as a sample, the tops of the wickets of the pass, when up, are 8 inches lower than those of the wickets of the weir, and they are 4 inches below the surface of the upper pool. Four inches is therefore the minimum depth of water that is expected to pour over the tops of the wickets of the pass. During this stage the water of the pool below stands against the back of the pass-wickets, at a vertical height of 4 feet 4 inches. Should the water get too low to give four inches over the tops of the pass-wickets, the dam can be tightened by temporarily covering the spaces left between the wickets.

The length of the shortest pool on the Upper Seine is 3.38 miles and that of the longest seven miles. The fall of the river between the Varennes and the La Cave Dams, a distance of 18.63 miles, is 23 feet, or an average of about 15 inches per mile, while between the same dam and that at Port-à-l'Anglais, a distance of 56 miles, the fall is 60 feet, which is an average of about 13 inches to the mile. The average fall of the Ohio in the first twenty miles of its course is 17 inches per mile, but this slope rapidly changes, and in the first fifty-six miles the fall is 53.3 feet, or at the rate of about 11½ inches per mile. The slopes of the two rivers, in the portions compared, are thus seen to be nearly the same, though the greatest floods in the Ohio, in the sections compared, vary from 35 to 45 feet, while in the Upper Seine they only vary from 16 to 23 feet. As might be expected from the greater height of floods, the banks of the Ohio are much higher above low-water than those of the Seine, and therefore higher dams can be built without greater danger of overflow.

One objection to all the French systems is that the mechanism consists of a great number of parts, all of which must be kept in perfect working order, a thing which is less difficult in France than in the former country because there is a long-established and well-organized and trained body of inspectors, engineers, lock and dam tenders, and assistants, whose lives are devoted to such work, and who are thoroughly capable of attending to it. The lack of such a body in the United States makes it eminently desirable that all machinery should be of the simplest possible kind, and we believe that the plan which we recommend has at least this merit.

Another and more serious objection to the French systems comes from the greater cold of our climate, and the greater danger of injury by ice. The account already given shows that the Seine dams were greatly endangered by an unusual cold of 21°. As this is a very common temperature with us, and as the thermometer is not unfrequently below zero, it is manifest that the danger mentioned would be both more frequently encountered in this country, and more dangerous when encountered, particularly in view of the higher and more sudden floods, and the greater masses of drift-wood. Therefore, with our present information, we think it would be better to test the Brunot gate in preference to adopting the French systems thus far in use. If the test is unsatisfactory, we still have them to fall back on, while if it is a success we believe that we will have a simpler, stronger, and more readily handled apparatus.

Should the system which we recommend for trial be adopted, we will find ourselves provided with a navigation that differs in many particulars from that used in France. In the latter country, as soon as the natural depth in the river is less than 5 feet, the passes are closed, and all navigation in either direction is carried on through the locks. On our system, if we can get a gate, as we think we can, that can be opened in two minutes, and closed in five, it will be quite practicable to keep up an intermittent down-stream navigation through the pass throughout almost the whole year, as the opening of the gate for not to exceed ten minutes at a time, (which, allowing for diminished discharge while being opened and shut, will make the total expenditure of water about equal to a full opening of the chute for 5 minutes,) will probably not injuriously lower the level of the upper pool. We would thus have a natural down-stream navigation throughout almost the entire year, which would be an immense advantage, since our heavy products, such as coal and manufactured iron, all go down the river. To counterbalance this advantage, we would have the disadvantage of forcing all up stream navigation, except in very high water, to pass through the locks. The latter would have to be higher than the French locks, and our expenditures for masonry and timber for the dam, and inclined plane, would much exceed theirs. To counterbalance this, we have simpler constructions, less complicated mechanism, (which is both very costly, and must be carefully watched and kept in order,) and probably less expense for attendance. It is, therefore, mainly on account of the special character of our climate and of our navigation, that we recommend that a system differing from those used in France be first tested, in preference to copying what are successful in their native country, but which might not work so well here. We wish it to be specially understood, that while we have attempted to collect all available information on this subject, we do not presume to decide the question now, but limit ourselves to recommending a preliminary experiment. Having, therefore, decided in favor of an experiment upon the plan proposed by Mr. Brunot, it now remains to elaborate its details.

There are two methods of filling the gate—by opening valves in the top of the gate itself, or by opening a pipe which communicates with the interior of the gate. As the gate rises and falls around a horizontal axis, there is some difficulty in devising an apparatus to move these valves at all times which shall itself be sheltered from floating bodies. Moreover, valves in the top of the gate are liable to injury, and they weaken the gate where it ought to be strongest. For these reasons we propose to permit water to enter by a pipe under the platform of the chute, which shall connect with the interior of the gate by several branches of flexible pipe entering just below the hinges. The main pipe will be controlled by a valve worked from the abutment, as shown in Fig. 92. It is calculated that a two-foot pipe will fill the experimental gate, 100 feet in length, in 2 minutes, which is, probably, quick enough. To empty the gate a centrifugal pump is used whose suction-pipe has a flexible length to connect it with a pipe extending to the bottom of the gate. This pump will be set in motion by a turbine wheel. The necessary power to drive this pump was calculated by assuming 5 minutes as the time for the work, and taking the capacity of the experimental gate as 5,000 cubic feet, and the lift as 6 feet. We, therefore, have a quantity of work of 375,000 foot-pounds per minute, or 11.4 horse-power. The effective work of pumps is given by Bourne as ranging from 30 to

65 per cent. of the power applied to them, and, therefore, with an assumed efficiency of 38 per cent. we find that we require 30 horse-power to work this pump.

To get the size of turbine necessary to develop this effective power, we use Francis's formula:

$$D = 4.85\sqrt{\frac{P}{h\sqrt{h}}}$$

in which $P = 30$, the effective horse-power, and
$h = 6$, the assumed head of water. We, therefore, find—

$$D = 6.93 \text{ feet.}$$

The amount of water necessary to supply this wheel is found by the formula, also given by Mr. Francis:

$$Q = 0.5\, D^2 \sqrt{h}$$

Whence we find—

$$Q = 58.8 \text{ feet per second.}$$

To supply this amount of water without great velocity, and, therefore, without sensible loss of head, the water in the channel leading to the turbine should have a velocity of not more than 3 feet per second; and, therefore, the cross-section of the channel should be about 20 square feet. We have, therefore, taken a width of 4 feet and a depth of 5. The positions of the pump and turbine are shown in Fig. 92.

It is important to have some arrangement for the automatic filling of the gate, should a sudden flood come in the night, or when the gate-tender was absent or negligent. This is provided for by a stationary pipe at the far end of the gate, which is sheltered from floating bodies by the recess at the end of the chamber. The height of this pipe is such that when there is a greater depth in the chute than seven feet, the water overflows into the gate. This pipe also answers as an air-pipe during the maneuvering of the gate.

The most important navigation on the upper part of the Ohio River is the transport of coal, and as this transport is always down stream, and as the ponderous coal-fleets are not easily checked or stopped, it is very desirable that the process of lowering the gate and opening the pass should be very expeditious, while there need be no great hurry in raising the gate. The system proposed answers these ends perfectly. One man can maneuver the gate, and it can be filled with any desired rapidity. If the 2-foot pipe should not do the work fast enough, there is no difficulty whatever in using one of greater diameter. After the fleet has passed, the attendant has only to open the gate of the turbine, and in a few minutes the pass is closed. It seems hardly possible to devise a system that could promise better results.

In order to scour out any sediment that may accumulate in the chamber, a culvert is made at the far end, and inlet pipes at the abutment. As this operation would seldom be necessary, (possibly once a year,) it is believed that the management of the valve at the far end would offer no practical difficulty. Excepting this one valve, all the mechanism is on the abutment, and is therefore always accessible.

Besides the gate, the shape and details of the pass require special attention. In order to acquire knowledge in the working of passes, or chutes, as they are frequently called, the board went to Lock Haven, in Pennsylvania, and examined the chute in the dam across the Susquehanna at that place. This chute and dam are shown in Fig. 36, plate 4. The length of the chute is 1,295 feet, and its width is 31 feet. The difference of level, in low water, between the pool and the river below, is 11 feet, and the slope of the chute is 1 in 142.

There is no gate at its head, as it is left open until the water above becomes too low, and then a temporary dam of plank, resting against a horizontal beam, is constructed. The chute was unfortunately closed when we visited it, but we obtained much information about it from an ex-officer of engineers, Mr. R. W. Petrikin, residing in Lock Haven. We learned that it was only used in running rafts down the river, and that there was a marked wave at its entrance, and also that rafts in passing out of the chute into the river were generally submerged. At the Williamsport chute, on the same river, rafts dive so much that in order to diminish this tendency they are forced to use, at the lower end of the chute, floating timbers with one end fastened to the bottom. Neither the wave at the head of these chutes nor the diving at the foot is injurious to rafts, but they would be to coal-fleets. A very important matter of detail is to make as much friction as possible on the bottom and sides of the chute, so as to retard the velocity of the water. The superiority of the Lock Haven chute to the others on the Susquehanna is attributed, in some measure, to the fact that it has a stone bottom, while others have wood. The stone paving has become so rough that it checks the current very appreciably.

The board believe that by a judicious widening of the head of the chute, so as to cause a large body of water to enter, the head-wave can be almost if not entirely obviated, and that a similar widening at the foot would probably work equally well there. But these and other details can only be settled by actual trial, and without such trial they would be unwilling to recommend the system for use on the Ohio. If it is a success, there need no longer be any difference of opinion about the radical improvement of that river. As such vast interests depend upon this trial, they would most urgently press its importance upon Congress.

To test the whole scheme, the Monongahela Navigation Company, who need something of the kind for their own use, offer the use of the lowest dam on the Monongahela for a chute 100 feet in width, or half the width proposed for ultimate adoption on the Ohio. The two locks in their dam No. 1 are insufficient to transact the rush of business that crowds upon them whenever there is a coal-boat rise in the Ohio, and many coal-barges lose an opportunity of getting to market on account of the impossibility of getting through the locks in time. If the chute proves a success, barges can safely lie in pool No. 1 until a rise comes, and then pass down the river promptly. An indirect result would be to add pool No. 1 to the harbor of Pittsburgh, which is now greatly overcrowded.

The Monongahela Navigation Company is, therefore, equally interested with the United States in finding a successful solution to the problem before us.

They therefore, through their president, Hon. J. K. Moorhead, offer for this purpose their dam No. 1, and agree to pay one-half the cost of the experiment, it being understood that in case of success they are to become the owners of the gate and chute.

This proposition seems to us a fair one to both parties, and we would therefore recommend its acceptance. According to the most careful estimate that we have been able to make, the cost of putting in a chute 100 feet wide, with a movable hydraulic gate, the bottom of the chute being 4 feet below the crest of the dam, will be $80,000. We would therefore urgently recommend the appropriation, by Congress, of $40,000 for the purpose of experimenting with a navigable chute, to be opened and closed by a hydraulic gate, in one of the dams of the Monongahela Navigation Company, provided that the chute and gate be constructed in accordance with the plans of the United States engineer in charge of the improvement of the Ohio River, and provided, also, that the Monongahela Navigation Company shall pay one-half the actual cost of construction, without any charge for the use of their dam or of such tools or working-machinery as they may have on hand. It should also be agreed that, in consideration of the foregoing provisions, the chute and gate shall become the property of the said Navigation Company, but that both chute and gate shall be subject to such changes or modifications, at the joint expense of the United States and the Navigation Company, as may be directed by the United States engineer in charge, until in his opinion further change or experiment is unnecessary. It should further be agreed that in case the experiment should prove a failure, the United States shall be liable for no charges for the cost of removing said chute and gate, and restoring the dam to its original condition.

There are still many details to be elaborated in the practical construction of the Brunot gate which the pressing necessity for an early report, and the unexpected amount of time and labor required to collect the foregoing information, make it impossibe for the board to complete. They believe, however, that they have sufficiently covered the subject in the foregoing, and would recommend that the duty of preparing the practical details of construction be assigned to the engineer in charge of the improvement of the Ohio River.

Respectfully submitted.

G. WEITZEL,
Major of Engineers, Brevet Major-General, U. S. A.
W. E. MERRILL,
Major of Engineers and Brevet Colonel.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

N 4.

IMPROVEMENT OF THE MONONGAHELA RIVER.

In my report of September 1, 1873, the progress of this work was given up to that date. This consisted in the purchase of land for the site of the proposed lock and dam at Hoard's Rocks, W. Va., and the letting of a contract for the construction of the lock.

Work was begun by the contractors in opening a quarry for stone in September last, and soon after the excavation for foundation was commenced. The progress of the work has thus far been slow, and I hardly think it probable that the contractors will be able to complete the lock this season, as contemplated by their contract. The excavation for the foundation is now complete, and a large quantity of stone of all classes is ready for the walls. From present appearances, not over five or six courses will be built by the close of the season. These, however, are the ones that are most troublesome and most subject to delay by rises in the river, and by land-slides. After they are finished, the work can progress smoothly and rapidly.

The funds appropriated for this work will probably be sufficient to complete the lock, and a small margin may be left toward building the dam. The additional sum of $22,000 will, however, be necessary to complete the improvement at Hoard's Rocks, being the difference between my estimate for the current year ($47,000) and the amount ($25,000) appropriated by act of June 23, 1874.

To complete the improvement of this river so as to properly connect with the slack-water system already established on the Lower Monongahela, will require two additional locks and dams, one of which should be built at or near Cheat River Ripple, and the other at Jacob's Creek.

In estimating for a lock at Cheat River Ripple, I only do so because a lock must be built at or near this place in order to carry out the system of improvement recommended by me and approved by Congress. The question as to who should build it is an open one, as this matter has never been settled; but presuming that my opinion would be desired, I give it herewith. I think that it would be better if the United States were to build this lock, although it is in the State of Pennsylvania. The Monongahela Navigation Company is bound by law to make a navigation to the State-line, but not beyond it. The Hoard's Rocks lock is beyond this line, and a good navigation cannot be made up to it without two more locks, or one, besides the one which the company must build. But should they comply with their obligation and build a lock with a lift of 16 feet, the one to be built by the United States need have only 4 feet of lift. The 16-foot lock would have a lift that experience has shown to be too great for useful service and the 4-foot lock would have an absurdly small lift. As a matter of law, I suppose that the navigation company could be compelled to build the lower 10-foot lock and pay a proportion of the cost of another lock of equal lift above. As a matter of expediency, however, I would recommend that the United States assume the entire cost, and, therefore, the undivided control of the lock at Cheat River Ripple, only requiring of the Navigation Company a relinquishment of all claim to control the navigation of that part of the Monongahela, and an agreement that the lock, which they must build, shall have 6 feet at low water over its own lower miter-sill, and shall raise the surface of the water 10 feet. Several of the locks on the present navigation have but 4 feet on their lower miter-sills in low water, but the Company is now engaged in raising its dams so as to give 6 feet, and my own calculations have all been based on a 6-foot navigation in the part of the river in the State of West Virginia.

If the United States should build the lock suggested it will require an appropriation of $110,000; I therefore make a contingent estimate for this amount, presuming that all legal questions as to its construction will be settled with the navigation company by the proper authorities.

ESTIMATE.

Completion of dam at Hoard's Rocks	$22,000
Dam at or near Cheat River Ripple, Pa	110,000
	132,000

A statement of the financial condition of this work at the close of the fiscal year is hereto annexed.

Financial statement.

Balance in Treasury of United States July 1, 1873	$90,000 00
Deduct amount expended in last fiscal year	409 14
Amount appropriated by act approved June 23, 1874	25,000 00
Amount expended during the fiscal year ending June 30, 1874	6,120 13
Amount available July 1, 1874, ($108,470.73 — $403.84)	108,066 89
Amount required for the fiscal year ending June 30, 1876	132,000 00

N 5.

IMPROVEMENT OF THE GREAT KANAWHA RIVER.

Mr. A. M. Scott has been my assistant engineer in local charge of the Government work on this river.

The first appropriation for the improvement of this river was made for the fiscal year 1873–'74, and my last annual report contains a statement of the contracts made under that appropriation, and an account of the work done under it up to September 1, 1873. The present report will bring up the record to August 15, 1874, at which date, in obedience to your orders, the work was transferred to Maj. W. P Craighill, Corps of Engineers.

The last annual report stated that contracts had been made for work at Cabin Creek Shoals, Elk Shoals, and Two-mile Shoal.

Cabin Creek Shoals.—Sixteen miles above Charleston, and seventy-three and a half miles above the mouth.

This contract was let soon after I took charge of the river, and before Mr. Scott, the superintendent, had an opportunity to acquire sufficient local knowledge of its peculiarities. It being important to get to work as speedily as possible, in order to utilize the low-water season, I told Mr. Scott to follow the advice of the Kanawha board, and make the best estimates that he could. The contractor for this work also got the contracts at Elk Shoal and Two-mile, and spent all his time on them. He died before he could begin at Cabin Creek, and his contracts passed into the hands of his executor. The latter asked to be released from the Cabin Creek contract, and Mr. Scott having concluded, after the preparation of a detailed map of the locality, that the proposed dike would not answer the purpose for which it was designed, recommended that the release be granted. For the reasons assigned by Mr. Scott, I approved of the application and you granted the release. The contract was therefore annulled, and no work has been done at Cabin Creek Shoals.

Elk Shoal.—Half a mile below Charleston, and fifty-seven miles above the mouth.

The dam at this point has been completed. The total amount of stone in the dam is 4,427 cubic yards. The original improvement consisted of a narrow chute, varying in width from 110 to 120 feet, bounded on each side by walls composed of loose stone and of material dredged to make the chute. This method of improvement was useful to packets, but injurious to coal-fleets, as the chute was too narrow for their use, and in consequence they ran entirely outside of it whenever the stage of water would permit. To remedy this, the right wall of the chute was removed, and the opening was made 100 feet wider, but the space taken in was left at a higher level than the bottom of the chute, in order not to increase the width of channel in dead low-water. This work was done by hired labor and has been completed. It necessitated the removal of 4,300 cubic yards of stone, gravel, and bowlders. The dike starts at the right bank, and connects with the new right-hand wall of the chute.

Two-mile Shoal.—Two miles below Charleston, and fifty-five miles above the mouth.

The dam at this place has been completed. There were used in its construction 4,128 cubic yards of stone and 79 cords of brush. It was built in order to stop the waste of water behind Blaine's Island.

REMOVING OBSTRUCTIONS.

My last annual report (p. 507, Report of Chief of Engineers, 1873) described the large grapple which I had caused to be made for use on the Great Kanawha and Ohio rivers, its special use being to raise large bowlders lying in the bed of the river, and too large to be lifted by any ordinary hoisting-apparatus. This machine has done admirable service, although it can only work occasionally, when the river happens to be low and clear.

In October, 1873, 112 large rocks and 10 snags were removed, and three wrecks of sunken coal-barges were torn to pieces in fourteen days.

The grapple was not used in the Kanawha again until July, 1874. During this month its work was as follows:

Cabin Creek.—Took 18 rocks from foot of shoals; deposited them in 11 feet water above Ault's Landing. Two lying in the right of channel were too large for the grapple, and were blasted and removed.

Witcher's Creek.—Removed from foot of shoal a large sycamore 100 feet long.

Machine Ripple.—Took twelve rocks from this place. Several of them were large and badly spike-marked.

Campbell's Creek.—Removed several logs from this landing.

Two-mile Shoal.—A large stump from Young Two-mile, and two logs from channel at mouth of creek.

Island Shoal.—Removed a stump 6 feet in diameter from foot of chute.

Tyler Shoal.—From head of chute, 4 big bowlders.

Peeled Maple.—Took out 25 big rocks and a large root.

One mile above Coal's Mouth.—Moved Christy's Rock to left shore.

Coal's Mouth.—Took a sycamore 100 feet long and 5 feet in diameter, with a bad root, from the landing.

Scary.—Removed 4 rocks and a snag from head of chute.

Near George Wright's Landing.—Took 2 big elms and a large rock from the middle of the river.

Tacket Shoal.—Four rocks from foot; one of them was very large and badly rubbed and marked.

Two mills below Tacket.—Took a large snag from the middle of the river.

Summer's Shallows.—Blasted and took out 2 large rocks.

One mile above Red House.—Blasted, and removed in five pieces a well-known troublesome rock.

Red House.—A big rock and a small snag from foot of shoal.

Little Hurricane Ripple.—Removed 9 rocks from head of chute.

Washington Shallows.—Thirteen bowlders.

Tucker's Creek Bar.—Took off 13 rocks.

Big Hurricane.—Moved 14 large rocks from this ripple.

Gillespie's Ripple.—Fifteen rocks from head; one, very large, was blasted and taken out, and a large sycamore from foot of ripple.

Vintreaux Shallows.—Nearly four days were spent in these shallows; in all 91 rocks were removed; several of them had to be blasted.

Mary's Shallows.—Took from lower end 23 rocks.

Knob Shoal.—Removed 4 dangerous rocks from foot.

Buffalo Shoal.—Removed 32 rocks here, several of them very large; considerable time spent.

Buffalo Shallows.—Removed 20 rocks; also a big snag from opposite Widow Sibbrell's landing.

Near Atkinson's Landing.—Took out a snag and 4 rocks.

Eighteen-Mile.—A bad rock from the ripple.

Arbuckle Shoal.—Removed 3 rocks from head and a very large elm from foot of chute.

Thirteen-Mile Shoal.—Six rocks and 4 troublesome logs.

Ten-Mile.—Two very large trees.

Three-Mile Bar.—Took out a bad sycamore snag about 75 feet long.

The Kanawha board were so much pleased with the work of this grapple in removing from the river many large rocks, that for years had been the terror of pilots, that at their request I had a design prepared for the smaller grapple, to be used by them in removing the smaller rocks, for which the large grapple was not well fitted.

PURCHASE OF MAPS.

The general map of the river which we use, was made by Messrs. Lorraine and Byers in 1856–'57. The set transferred to me by Major Craighill was incomplete, but negotiations were then in progress for the purchase from the widow of Mr. Byers of the missing maps and profiles. With the approval of yourself and of the Secretary of War, I purchased these documents from Mrs. Byers for fifteen hundred dollars. Our general map is therefore complete.

During the year, Mr. Scott, with one assistant, has been employed in copying and arranging the purchased material, and in making detailed surveys at places where improvements were contemplated. Detailed maps on a scale of one inch to 200 feet have been made of Cabin-Creek Shoal, Witcher's Creek Shoal, and of the river from Charleston to the foot of Wilson's Island.

NEW APPROPRIATION.

At its last session Congress appropriated $25,000 for the improvement of the Great Kanawha. As I have been directed to transfer the charge of this river to Major Craighill, I offer no project for the expenditure of this sum; nor do I submit any estimate for the fiscal year 1875–'76.

Financial statement.

Balance in Treasury of United States July 1, 1873	$25,000 00
Deduct amount expended in last fiscal year	352 98
Amount appropriated by act approved June 23, 1874	25,000 00
Amount expended during the fiscal year ending June 30, 1874	14,322 21
Amount available July 1, 1874, ($35,324.81—$800.54)	34,524 27

N 6.

IMPROVEMENT OF THE WABASH RIVER.

Mr. F. Stein has been my assistant engineer in local charge of this work.

The work of snagging and dredging in the lower end of the river and the rock-excavation and construction of wing-dam at Coffee Island Chute, all of which were under contract with Mr. R. Mackenzie, dated August 27, 1872, have been completed, and the contracts closed. The following is a summary of the work done under this contract:

Snagging in the lower river, 134 days.
Dredging in the lower river, 115 days.
Rock-excavation at Coffee Island Chute, 10,809,65 cubic yards.
Wing-dam at Coffee Island Chute, 40,307 cubic yards.

Of this work 103 days' snagging, 79 days' dredging, and 6,450 cubic yards rock-excavation were done in the fiscal year 1872–'73, as previously reported. The remainder was done during the last fiscal year.

The river is now clear of snags and obstructions, and has had its channel dredged for a distance from its mouth of 31 miles. The improvement of Coffee Island Chute one hundred and three miles above the mouth does not connect immediately with the improvements on the lower end of the river, but this place was selected by my predecessor, Major Weitzel, because at the time the available funds were insufficient to complete any more important improvement.

Under the appropriation of March 3, 1873, ($50,000,) a contract was entered into with Messrs. Myers and De Ham for 23,000 cubic yards of rock-excavation at the Grand Chain, thirty-eight miles from the mouth of the river. This work was begun during the month of August, and was continued until December; 14,710 cubic yards of excavation were made during this time, leaving 8,290 cubic yards still to be removed. The contract provides that this work shall be completed by December 1, 1873, and work on it is now in active progress.

The next point which is in pressing need of improvement is the Grand Rapids, one hundred and twelve miles from the mouth of the river, at which place the ruins of a lock and dam constructed by the Wabash Navigation Company aggravate the natural condition of things, and render these rapids impassable, except in high stages of water. I would respectfully refer to my last annual report (Report of the Chief of Engineers for 1873, p. 511) for a full history of the lock and dam and its present relation to the improvement of the river.

Deeming it indispensable that the Grand Rapids should be overcome by the reconstruction of a lock and dam, a special survey was commenced, and at the close of the fiscal year was still in progress, to determine whether the new lock should be built upon the site of the old one, or be placed about two miles further down and just below the mouth of White River. The advantages of the latter location are that a lock and dam here would obviate the necessity of any further improvement of the White River Shoals, and would at the same time improve the navigation of the White River. Since the close of the fiscal year this survey has been completed, and from it I conclude that, on account of the lowness of the banks of the Wabash and of the White in the vicinity of the proposed site at White River Shoals, it would be inexpedient to remove the dam from its present position, and therefore I recommend the retention of the old site.

An appropriation to rebuild the Grand Rapids Lock was asked for in my last annual report, but, by act of June 23, 1874, Congress appropriated only $25,000 for continuing the improvement of the Wabash River, adding a proviso:

> That a portion of this appropriation, not exceeding $9,000, may be used by the Secretary of War, in his discretion, for the extinguishment of any right, title, or claim of the Wabash Navigation Company in the lock and dam at Grand Rapids, on said river, and other property said company may claim on said river; and for the extinguishment of any right said company may have to affect or interfere in any way with the navigation of said river; but no part of this appropriation shall be expended until said navigation company shall have relinquished all right to control or otherwise, in any manner, interfere with or affect the free navigation of said river.

This proviso forbids any new work on the Wabash until the rights of the Navigation Company have been extinguished. A proposition for the sale of their rights and franchises has been received from this company, and has been referred to the proper authorities for action. After the purchase is made, a project for the application of the remainder of this appropriation will be submitted to the Chief of Engineers.

ESTIMATE FOR YEAR 1875–76.

For rebuilding the Grand Rapids Lock	$110,000
This sum does not include the amount necessary for reconstructing the dam, as it is thought better to defer the building of this part of the work until the completion of the lock, for which at least one season will be required.	
For clearing out the chute east of the Little Chain	6,000
This is one of the points named by Major Weitzel for improvement in his report dated January 4, 1872, (Report to the Chief of Engineers, 1872, p. 472.) The object of this estimate is simply to remove snags, large numbers of which have lodged here. It is expected that when these are removed the action of the current will sufficiently widen and deepen this chute, and thus enable steamboats to entirely avoid the Little Chain.	
For contingent expenses	14 000
Total	130,000

The construction of a dam at New Harmony to close the cut-off at that place, and thus retain in the main channel the whole volume of the river, is very much needed. I have omitted this work from the above list, because I hope to be able to build this dam out of what is left of the year's appropriation after the purchase of the lands and franchises of the Navigation Company.

A statement of the financial condition of this improvement is hereto annexed.

Financial statement.

Balance in Treasury of the United States July 1, 1873	$65,000 00
Amount in hands of officer and subject to his check, (including $2,772.83 percentage due on contracts not yet completed)	5,542 40
Amount appropriated by act approved June 23, 1874	25,000 00
Amount expended during the fiscal year ending June 30, 1874	47,558 35
Amount available July 1, 1874, ($47,984.05—$2,647.80)	45,336 25
Amount required for the fiscal year ending June 30, 1876	130,000 00

N 7.

WATER-GAUGES ON THE MISSISSIPPI RIVER AND ITS PRINCIPAL TRIBUTARIES.

No annual inspection was made during low-water of last autumn, the proper season for inspecting, as Lieutenant Mahan, to whom I had assigned this duty, was suddenly ordered by telegraph to proceed to Savannah, and I had no one whom I could send in his place. As the gauges were generally in good order, I thought it advisable to dispense with an inspection, and to put the sum thus saved into the reconstruction in a permanent manner of such gauges as were located where the banks were of sufficient stability to permit such construction.

Fort Leavenworth gauge.—This gauge is in good order, and has given no trouble during the past year. The Missouri River was closed by ice from the 4th to the 27th of January, and from the 31st of the same month to the 4th of March, though during this period it was frequently open in places. The first ice in the river was on the 28th of November. Mr. W. N. Metz is still the gauge observer.

Rock Island gauge.—This gauge is a permanent one, being cut on the pivot-pier of the draw of the Government bridge. The first floating ice appeared in the latter part of November. The ice began to break up about 3 p. m. on the 8th of March, (gauge reading, 11.40,) and gorged at 4 p. m., opposite Rock Island water-works, (gauge reading, 14.90

and 15 at 5 p. m.) On the night of the 9th the water rose to 15.75, but the gorge held fast. On the 10th, the ice finally moved off. Mr. G. F. Evans has been the gauge-observer throughout the year.

Saint Louis gauge.—Since the date of my last report I have had a substantial iron gauge constructed on the city wharf at the place where the old records were taken by levelings, before the signal-service gauge was placed at the elevator. The exact location of the gauge is opposite No. 4 South Front street. The construction is similar to that first used at Memphis, and described in my report of February 19, 1872. (Report of Chief of Engineers, 1872, p. 426.)

Piles from 10 to 15 feet in length, and 8 feet apart, were driven on the line of the gauge. These were capped by an 8-inch stringer, and on this was firmly spiked a railroad-rail. The paving of the wharf was then re-set close up to the rail, leaving nothing visible after the work was done but the top of the rail, on which the gauge was marked with steel stamps. The zero of the new gauge is the low water of 1863. The reading on it of the city directrix is 33.81. The gauge extends to 2 feet below low-water, its lower end being supported by two extra piles and beams. For its engineering, I am indebted to Mr. Julius Rapp, assistant to Mr. J. B. Moulton, the city engineer. The latter gentleman gave me all the facilities of his office, and whatever assistance and information I needed.

In order to correct erroneous back records, I directed Mr. Leopold, the gauge-observer, to take synchronous observations on the gauge at the elevator, and on the new iron-gauge. These observations did not give very satisfactory results, as the difference in the readings varied at the same stage in the river. After comparing the differences graphically and numerically, I established the following table of corrections, to be applied to the readings on the gauge at the elevator:

Between 4 and 7 subtract	0.80
Between 7 and 11 subtract	0.80
Between 11 and 14 subtract	0.90
Between 14 and 17 subtract	1.00
Between 17 and 19 subtract	1.05
Above 19 subtract	1.10

The gauge-records which I send herewith have been corrected on this system.

Mr. Jacob Leopold continues to be gauge-observer.

Cairo gauge.—As Cairo is the most important point in the Mississippi Valley for water-gauge observations, I had even stronger reasons for constructing a permanent gauge here than at St. Louis. The old gauge at the freight-warehouse had become warped by the sun and injured by the chains and cables of steamboats, and besides it was at a distance from the main wharf. The place chosen for the new gauge is at the lower end of the paved wharf at the foot of Fourth street, the old one having been at the foot of Fifteenth. The distance between the two gauges is 2,830 feet.

Owing to the instability of the Cairo levee, Mr. Charles Thrupp, the engineer in charge, thought it advisable to support the stringer on small trestles with mud-sills. These trestles have 6 by 8 inch caps, 6 by 6 inch posts, and a 12 by 4 inch mud-sill. The posts are fastened to the cap by tenons and treenails, and to the sill by wedges and spikes. The stringer is of oak, with a section 8 by 12 inches, and is firmly fastened to each trestle-cap by $\frac{3}{4}$-inch screw-bolts. The trestles are 4 feet in height and 6 feet apart. The gauge proper is an iron bar 4 by $\frac{1}{2}$ inch countersunk into the stringer. The gauge is a first-class one in every respect, and reflects great credit on Mr. Thrupp. The zero of the new gauge is at the same level as the zero of the old one. Mr. M. S. Ensminger, the city wharf-master, continues as gauge-observer.

The following bench-marks in Cairo were communicated in December, 1867, to my predecessor in charge of the Ohio River, Mr. W. Milnor Roberts, by Mr. J. P. Hely, engineer, Cairo City property. They are here recorded for future use. They are referred to the city datum-line, which reads on the United States gauge 9.16.

Grade of Ohio levee	42.60
Grade of the Illinois Centra Railroad on Ohio levee	43.00
Grade of Mississippi levee	44.00
Door-sill St. Charles Hotel, northeast corner	43.26
Door-sill Adler's store, between Fourth and Sixth	43.63
Door-sill Donelly's store, between Eighteenth and Twentieth	43.78

Upper Louisville gauge.—The observer at this station has also charge of the gauge at the foot of the canal, the two gauges being about two miles apart. The upper gauge is also repeated on the wall just above the guard-gates, in close proximity to the lower gauge. I therefore concluded that it would be better to stop reading the gauge at the head of the canal, and to take both readings at the guard-gates. The readings herewith forwarded were thus taken.

Lower Louisville gauge.—In my last report I stated that the stone-cutter who cut the first gauge had made an error which amounted to about 5 inches in the highest reading. With the assistance of Capt. M. B. Adams, Corps of Engineers, who kindly superintended the work, I have had a new gauge cut at the foot of the canal which is correct. Mr. William Reynolds was the gauge-observer until May 3, since which time the record has been kept by Mr. J. B. Thompson.

Nashville gauge.—There being no gauge on the Cumberland River, I asked Mr. S. Thayer Abert, then in charge of the work on the Cumberland River, to construct one for me at Nashville, requesting him, if possible, to put in an iron-gauge. As the natural shore at the Nashville wharf is solid rock, the method of constructing the substructure varied somewhat from the method used at St. Louis and Cairo.

The following is taken from Mr. Abert's report:

> The trench for the foundation has been excavated, partly in rock, partly in compact clay. Upon this bed, sills 6 by 6 inches by 4½ feet, placed every 6 feet, support a continuous string-piece of the same dimensions and 12 feet long, halved and spiked at the joints and the sills beneath. Upon this, rolled iron, 4 by ⅝ inches by 16 feet, is laid, with ends abutting, and secured to the string-pieces with four 1-inch spikes at distances apart of 1 foot, and upon alternate edges of the iron. Screws were used at road-crossings, as the cedar, although five times as durable as oak, does not hold nails so well. The gauge is protected from 18 inches to 2 feet on each side with substantial paving. The upper end terminates on Front street, but does not cross it. The observation of floods above this point must be transferred to the marks on Harrison's store. A line has been cut, at every distance equivalent to one vertical foot, with a cold-chisel. In some cases these marks cross the iron obliquely, on account of the difference of level in the two sides; a small difference in elevation making a noticeable difference in distance.
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> The low-water reference is 1 foot below the low-water of last summer, and very near extraordinary low-water. The following levels are referred to the same zero:

Top of second course of Wood & Simpson's boiler-shop	33.76
Top of curb-stone at lamp-post, Harrison's corner	48.811
Top of curb-stone at southwest corner Broad and Front streets	50.066
Top of sill-course, (marked x,) Harrison & Son's corner	50.76
True high-water mark, Harrison's corner, notched 1847	54.667
High-water mark in paint, Harrison's corner, 1847	55.167

The entire length of the gauge is 304 feet. High-water mark 54.667 is 165.000 on the city-levels. Regular gauge-observations began on the 17th of August, 1873. Mr. H. H. Harrison is the gauge-observer.

Florence gauge.—This gauge has required no repairs during the year. Mr. W. P. Stradford is still the gauge-observer.

Memphis gauge.—This gauge was partly constructed by me and partly by the city of Memphis, (Report of Chief of Engineers, 1872, p. 430.) I regret to state that the lower portion of the city's part had to be taken up on account of the caving into the river of that part of the wharf on which it was built. This gauge therefore needs repair. It will be difficult to make a permanent gauge at Memphis until the city protects the foot of its wharf below low-water by riprap or similar covering. I urged this when the gauge was first constructed, but without succeeding in getting my recommendations adopted. Mr. W. L. Trask continues as gauge-observer.

Jacksonport gauge.—No repairs have been needed on this gauge during the past year. Mr. W. E. Bevens is still the gauge-observer.

Little Rock gauge.—The lowest section of this gauge is of wood, fastened to the vertical timber-wall at the foot of the wharf. During very low water, mud and sand accumulate so rapidly at the foot of the gauge that a trench must be dug every morning to get an observation. I thought of remedying this difficulty by duplicating the lowest section of the gauge by cutting it on the rocks above the landing. The lowest bid I could get for this work was $150, and therefore I abandoned the idea. On the night of the 5th of February the brick house to which the upper section of the gauge was attached was destroyed by fire, but the gauge, which was fastened on the outer wall of the cellar, was not injured. Since that time the owners of the building have been ordered by the city authorities to take down the walls. The gauge needs inspection and probably a partial reconstruction. Mr. Joseph Meyer is still the gauge-observer.

Helena gauge.—The gauge at this place was injured in July, 1873, by a coal-barge standing on it, but the observer made temporary repairs and kept it in fair condition. In June, 1874, he reported that the gauge needed reconstruction, as some of the sections were inaccurate from settlement, and others had been injured by drift and barges. He thought that the bank should be graded, and a heavier gauge constructed. I authorized this work to be done, but directed that the gauge should not be marked without orders. The reconstruction of the gauge is yet incomplete. Mr. J. B. Miles continues to be gauge-observer.

Gauge at mouth of White River.—This gauge needs a total reconstruction, and it may be advisable to change its location to Terrene, on the Mississippi shore. In my last report I stated that the old gauge had been carried away by the caving of the banks. Being unable to send any one to White River at the time, I directed the observer to make a new guage on the plan of the old one, and mark it as accurately as he could. This gauge also was destroyed in June, 1874, and the observer was directed to reconstruct it, the greater part of the material having been saved. This has not yet been done, and the record is kept by temporary marks. Capt. F. C. Kendall has been the observer during the year.

Lake Providence gauge.—In July, 1873, the falling of the river revealed the fact that below the 24-foot mark the guage was gone, probably destroyed by the ice of the preceding winter. The record has since then been kept up by temporary stakes. The gauge probably needs reconstruction. There is a duplicate high-water section of this gauge that will keep an accurate record of floods, even should the whole of the original gauge be washed away. Mr. S. T. Le May is still the gauge-observer.

Vicksburg gauge.—The observer of this station reports that he thinks that the elevator-piles to which the gauge is attached have settled, and he recommends an instrumental examination. This matter, however, has been unavoidably postponed. Mr. D. P. Fithian has been the gauge-observer during the year.

Natchez gauge.—There has been no trouble with this gauge during the past year. The bench-mark on Mrs. Cann's house having become endangered by the rotting of the wooden door-sill, the observer had a new bench established on the iron door-sill of Ray & Grant's store. Mr. L. F. Carvey was the observer from April 27, 1873, until his decease, on the 11th of August, 1874. The gauge is now under charge of Mr. J. B. O'Brien.

Red River Landing gauge.—On August 3, 1873, the observer at this station reported that the lower section of the gauge was missing. It was temporarily, but erroneously, established by a local engineer, and finally reconstructed by Mr. C. W. Babbitt, of Natchez, whom I sent there for that purpose. He found that 36 feet of the gauge required reconstruction, due to the slipping of the banks and the shock of a loaded barge. Maj. A. D. Smith continues to keep the gauge-records.

Alexandria gauge.—The lower section of this gauge was frequently broken by steamboats striking against it, so that it became necessary to reconstruct it more securely. The observer employed Captc R. W. Bringhurst, the parish surveyor, for this purpose. He used 8 by 10-inch stringers, on uprights of the same cross-section, 3 feet in length, supported on sandstone. The top of the stringer is even with the natural surface of the bank. The length of gauge replaced was 56 feet. Notwithstanding the care taken, the gauge was again broken in February. It could not be repaired until the present month. Capt J. A. Williams has been the observer since the gauge was established..

Baton Rouge gauge.—On the 5th of July, 1873, the observer reported that the second upright post was missing, and that a part of the inclined gauge was gone. The damage is supposed to have been done by a raft-log. A temporary post was at once put in the place of the missing one. As the water continued to fall, it was found that the lowest post was out of plumb, having been struck by a raft. This post was straightened and made serviceable. In October the gauge was carefully examined and put in good order by Mr. J. T. Van Pelt, civil engineer. His report contains the following interesting items, that should be preserved:

> It may be deemed important by the Department to have on record the following connections, or points of reference, which have been made by me at various times, and which have been carefully checked:

Mark on northeast corner of chimney of old mill near the gauge............	35.909
Top of stone bourn, at boundary-line between United States garrison and city property..	34.111
Bench-mark on State-house, known as the State-house bench-mark, which I think that Colonel Merrill used as his starting-point....................	62.570
Low-water 1854, (by Waller's records = 62.370 below State-house bench-mark)	0.200
Low-water 1851, (by Waller's records)..................................	3.200
High-water 1851, (by Waller's records = 34.33 above low-water 1854)......	34.530
High-water 1862, (by Waller's records = 35.870 above low-water 1854).....	36.070
High-water 1869, (measured by a citizen, 4¼ inches over the stone bourn)....	34.446
High-water 1871, (observed at the time by Van Pelt).......................	34.520

> The above readings differ somewhat from those of Colonel Merrill in 1872, but they are the result of three lines of levels run, first, by S. W. Hill, April 20, 1871; second, by myself, May 20, 1872; and, third, by myself and Colonel Lockett March 31, 1873. The three sets of levels, and especially the last two, agree closely. The above is an average of results.

These results are doubtless more correct than mine, which were obtained very hurriedly and under unfavorable circumstances, and I think that they merit preservation. Colonel Lockett resigned his post as gauge-observer in June, 1873, since which time the gauge has been in charge of Mr. W. N. Van Pelt, the business-clerk of the University of Louisiana.

Carrollton gauge.—In March, 1874, the observer at this gauge reported that two of the sections of the gauge which overlapped differed 0.15 in their readings. I at once wrote to Captain Howell, Corps of Engineers, and requested him to have the gauge examined. He directed Lieutenant Quinn to make the examination, and the latter reported that the section nearest the shore had settled 0.262 foot, and the next section 0.162 foot. The other sections were under water. Captain Howell promised to have another examination made in low water. On the 3d of the present month (August) the observer informed me by letter that the wharf had slipped into the river, carrying with it the gauge and its nearest bench-mark. Mr. William B. Williams, civil engineer, was employed to put in a temporary gauge, and observations for the present are taken from it. Mr. W. L. Duffy is still the gauge-observer.

Having at my own request, made on account of the pressure of other duties, been relieved from the future charge of these water-gauges, I will add a brief classification of them, as they appear to my mind after three years' experience.

The gauges at Rock Island, St. Louis, Cairo, Louisville, and Nashville may be considered as entirely permanent. Those at Fort Leavenworth, Jacksonport, Florence, Memphis, and Little Rock as semi-permanent; but the others require constant watching and continual repairs. The most suitable station for the officer in charge is at the point most central to the unstable gauges, and this condition is admirably filled by Vicksburg, the station of my successor. The system thus far carried out has been of great value to the planting and navigation interests, and I strongly recommend its continuance. It is for this reason that I have made all the gauges as permanent as their sites would permit. The Cairo gauge is much the most important of the system.

RECORDS OF THE FLOOD OF 1874.

I directed all gauge-observers to send to this office all information that they could obtain about the flood of this spring. I had intended compiling this information for this report, but as the whole subject has lately been referred to an engineer board, to whom I have been directed to turn over all the information in my possession, it is evidently unnecessary for me to discuss the subject.

I send herewith the gauge-records for the fiscal year 1873–'74 at the above-mentioned gauge-stations. The St. Louis record commences in 1861, and would have been forwarded last year but for certain errors, which have since been corrected.

Financial statement.

Balance in Treasury of United States July 1, 1873	$5,000 00
Amount in hands officer and subject to his check	813 37
Amount allotted from appropriation of June 23, 1874, for examinations and surveys	5,000 00
Amount expended during the fiscal year ending June 30, 1874	5,787 16
Amount available July 1, 1874	5,026 21

N 8.

EXTENSION OF THE CHESAPEAKE AND OHIO CANAL TO THE OHIO RIVER.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, March 20, 1874.

GENERAL: The act of Congress approved March 3, 1873, making appropriations for rivers and harbors contained the following clause: "And not to exceed $5,000 of the above appropriation may be expended in an exploration of routes for the extension of the Chesapeake and Ohio Canal to the Ohio River by the north and south branches of the Potomac River."

The duty of making this exploration having been assigned to me, and being unable, on account of my other duties, to make the survey in person, I considered myself fortunate in being able to put it in charge of Col. Thomas S. Sedgwick, late of the volunteer service, who had served under my command in the earlier years of the late war. His report is herewith forwarded.

The idea that there ought to be a canal from tide-water to the Ohio, via the valley of the Potomac, is a very old one, and was a favorite scheme of Washington, who was a stockholder in the Potomac Company, an organization that began work by attempting to improve the channel of the Potomac. Their efforts, however, were abortive, and the project slumbered until it was revived in 1824, under the auspices of the National Government. During this year, and 1825 and 1826, very careful surveys were made along the entire line of the proposed canal from Washington to Pittsburgh, special care being given to the manner of crossing the mountains. The results of these investigations are given in the copies of the Reports of the Board of Internal Improvements, which are herewith attached as Appendix A.

The object of the surveys of fifty years ago was to discover a practicable water-route between the Potomac and the Ohio. As the eastern division of the proposed canal (that portion lying in the valley of the Potomac) has been built as far as Cumberland, I inferred that my duty was to ascertain how to extend this canal toward the Ohio. The act itself required the survey to be made "by the north and south branches of the Potomac." As the limited sum at my disposal made it impracticable to run more than one instrumental line, and as the south branch of the Potomac enters the main river seventeen miles below the present head of the canal, and flows from a direction almost at right angles to the general line of canal, if Pittsburgh be considered as its objective point, I decided to restrict the examination to the north branch of the Potomac. Mr. Benjamin Latrobe, late chief engineer of the Baltimore and Ohio Railroad Company, very kindly placed at the service of Colonel Sedgwick all of the information which he had acquired while surveying to ascertain the best route for a railroad over the mountains, and gave it as decidedly his opinion that it was useless to seek, south of the Baltimore and Ohio Railroad, for a pass through which to carry a canal whose western terminus was designed to be at Pittsburgh. If there were an intention of making a connection with the proposed James River and Kanawha Canal, then the valley of the south branch of the Potomac should be surveyed, but inasmuch as I could hear of no such intention among those interested in the extension of the Chesapeake and Ohio Canal, and as such a canal, even if built, would probably be unable to divert any through traffic from the shorter and easier line down the James River, I concluded to abandon the south branch entirely. This survey was therefore restricted to a line via the north branch of the Potomac.

The Board of Internal Improvements, in 1825, reported a feasible route via North Branch, Savage River, Crab-Tree Creek, Deep Creek, and the Youghiogheny. In 1826 they reported a much better route, at a lower elevation, by way of Wills Creek, Flaugherty's Creek, and Casselman's River to its junction with the Youghiogheny and the other canal line. The route over the mountains, which Colonel Sedgwick selected for examination, was intermediate between these two. Commencing at Cumberland, it followed the North Branch, Savage River, and Blue Lick, and then, by a tunnel, struck Casselman's River at the Plucher reservoir of the Wills Creek route; thence it followed down the Casselman until it joined the Wills Creek route at the mouth of Flaugherty. The details of these three routes are given in the accompanying documents.

The following is a tabulated statement of the more important features of the three routes between Cumberland and the mouth of Casselman. The route recently surveyed is called, for distinction, the Savage River and Blue Lick route.

Comparison of lines for crossing the mountains.

Routes and dimensions.	Deep Creek route.	Wills Creek route.	Savage River and Blue Lick route.
Length from Cumberland to mouth of Casselman .... miles..	88.59	70.57	100
Length of tunnel at summit .... miles..	1.33	4.05	5
Elevation of summit-tunnel above tide .... feet ...	2,408	1,972	2,100
Lockage from Cumberland to tunnel .... feet ...	1,804	1,368	1,496
Lockage from tunnel to mouth of Casselman .... feet ...	1,070.5	634.5	762.5
Total lockage between tunnel and mouth of Casselman .... feet ...	2,874.5	2,002.5	2,258.5
Length of summit feeders .... miles..	12.0	6.0	0.1

In preparing the above table it became necessary to determine the elevation above tide of the Cumberland bench-mark. The surveys of 1828, and the construction of the canal, showed that there was an error of 69 feet in the levels of the eastern section of the canal as surveyed under the direction of the Board of Internal Improvements. The bottom of the canal at Cumberland is 603.75 above tide, and its surface 609.75. The Government bench-mark was found to be at the elevation of 632.27 feet above tide. An error in leveling was also found between Cumberland and the Wills Creek tunnel. As the latest survey put this tunnel definitely at 1,972 above tide, that height has been considered as established, and the Deep Creek tunnel has been placed 436 higher, according to the relative difference of level found by the Board of Internal Improvements. The lockages up to the three tunnels have been calculated from the present level of the canal at Cumberland.

A slight examination of the above table shows that the Wills Creek route is greatly superior to the other two, being shorter than either of the others, and having a much lower summit-level. It is eighteen miles shorter than the Deep Creek route, and has 872 feet less lockage, which is equivalent to dispensing with 109 locks. It has a longer tunnel, but this disadvantage is more than counterbalanced by the other great advantages. As compared with the Savage River and Blue Lick route (the new route surveyed by Colonel Sedgwick) it is twenty-nine and a half miles shorter, has 256 feet less lockage, and its summit-tunnel is one mile shorter. It is, therefore, a better route in every respect. Comparing the Deep Creek route with that by Savage River and Blue Lick we find that the former is eleven miles shorter and has a much shorter summit-tunnel, but has 616 feet more lockage. As far as time of transit is concerned we may assume that eight minutes are required at each lock for passing a boat through, which is equivalent to one minute for each foot of lift. The 616 feet of extra lockage would therefore require six hundred and sixteen minutes, or ten hours and sixteen minutes, during which time a boat could travel thirty-one miles on a level. As far, therefore, as speed of passage is concerned, the new route is twenty miles shorter in distance, or six hours and forty minutes quicker in time, than the Deep Creek route.

But there is always difficulty in maintaining enough water for navigation in very short levels, and therefore it is very desirable to have the locks as far apart as possible. Both of the last-mentioned routes follow the same line going west as far as the mouth of Crab-Tree, and therefore we need only compare them west of this point. On the Deep Creek route the heads of the lock would be at an average distance apart of 351 feet, but the Board state that " this is on the supposition of a uniform declivity, which is far from being the case, and more especially in the valley of Crab-Tree Creek, where, toward the head, the locks on account of the steepness of the ascent could not even find room, unless their lift should be considerably increased. To this difficulty we must add the narrowness of the valley, which would oblige to resort to very expensive means to erect, where necessary, double sets of locks, as also to shelter the work from destruction either by high freshets or by heavy showers."

On the Savage River and Blue Lick route the average distance between the heads of locks from the mouth of Crab-Tree to the eastern portal of the tunnel is 651 feet, and there is no difficulty in preserving this average throughout this part of the line. This is a very great advantage. Another advantage is that the new route, immediately after crossing the summit, enters a rich coal-basin (the Salisbury) on the other side of the mountains. As far as known, the country on the Deep Creek route, between the mouths of Crab-Tree Creek and Castelman River has no mineral resources and would furnish but little business to the canal.

If, therefore, a choice were necessary between the Deep Creek and the Savage River and Blue Lick routes, I think that the preference should be given to the latter, although it is proper to state that the long summit-tunnel will cause detentions that will appreciably reduce the gain in time over the Deep Creek route.

An inspection of the map shows that the only other possible route for a canal between Cumberland and Pittsburg, besides those already examined, is by way of the North Branch to its head, and thence across the mountains to the Cheat River. To this route there are several objections.

1. The approximate height of the head-waters of the North Branch at Fairfax Stone (as shown by Colonel Sedgwick's reconnoissance) is 2,520 feet above tide, showing that a tunnel in this vicinity would have a greater elevation than on any other line, and that, therefore, this line would require a much greater number of locks.

2. If the canal did not turn off before reaching the head-spring, it could not be supplied with water.

3. A route by the North Branch and Cheat River would be greatly longer than by any other line.

4. The Cheat River is an exceptionally wild and difficult stream, and

the maintenance of a canal alongside of it would be very difficult and costly.

(For a description of Cheat River see Appendix A, page 513.)

5. Along this line the country is very sparsely settled, and there would be but little business for a canal.

Any route passing south of the North Branch would be still more objectionable.

We therefore conclude that, in extending the Chesapeake and Ohio Canal, the choice of routes is absolutely limited to the three mentioned above. In order of desirability they are as follows:

1. Wills Creek route.
2. Savage River and Blue Lick route.
3. The Deep Creek route.

As by the appropriation act I was debarred from having an instrumental examination made of the Wills Creek route, my knowledge of it is limited to the older surveys and what could be seen while passing over the railroad between Cumberland and Pittsburg, which, except at the summit, occupies throughout its whole length the location chosen for the canal. The valley of the Little Wills Creek is so narrow and so wild, that it is doubtful if the railroad has left room for a canal; but this route is so greatly superior to any other, that, in my opinion, no work should be done toward extending the canal until a very careful examination is made of this line, to ascertain if it is still practicable for a canal. As far as the Salisbury coal-basin is concerned, it could more readily be reached by the Wills Creek route (if the feeder from Pleucher's were made navigable) than by the Savage River and Blue Lick route, as the distance from Salisbury to Cumberland via Wills Creek is forty-three miles, while by the Savage River it is fifty-seven.

But a canal by any of these routes is so very costly, that local advantages must be entirely subordinated to the principal object of the expenditure. In this case a connection between the Potomac and the Ohio is the evident solution desired, and therefore the line chosen for the canal should be such as will give the most useful connection, regardless of local interests.

After crossing the mountains the next question is how to descend the valley of the Youghiogheny. No instrumental survey could be made of this part of the route, but enough was visible from the cars to indicate that there would be considerable difficulty in this valley, especially at Ohio Pile Falls. The route recommended by the Board of Internal Improvements has been occupied by the railroad from Cumberland to Pittsburg, and an effort must be made to find room for the canal on the other side of the river. I would, therefore, recommend an appropriation for this purpose.

In order to test the value of Colonel Sedgwick's estimate of the cost of the summit-tunnel, I applied to the authorities of the Baltimore and Ohio Railroad for a statement of the cost of the Sand-Patch tunnel, which is at about the same place, though at a higher elevation, as the proposed Wills Creek tunnel. Mr. Latrobe very kindly gave me full particulars, and, with his consent, I append his letter as Appendix C. This tunnel, 4,800 feet long, cost $420,000, or at the rate of $87.50 per running foot for tunnel and approaches. The section, in the clear, of the Sand-Patch tunnel is 16 by 18½, while that of the proposed canal-tunnel will be a segment, 26 feet in height, cut from a circle whose radius is 16 feet. The area of excavation for the Sand-Patch tunnel is therefore about 330 square feet, and that of the proposed canal-tunnel about 800 square feet. The latter is, therefore, two and four-tenths larger than the railroad-tunnel.

Colonel Sedgwick places the cost of his five-mile tunnel at $8,346,000, which is at the rate of $1,669,200 per mile, or $316 per running foot. At this rate a tunnel of the sectional area of the Sand-Patch tunnel would cost $132 per running foot, which is 51 per cent. more per running foot than the latter tunnel actually did cost. A wide tunnel is less costly per cubic yard than a narrow one; but, on the other hand, a long tunnel is more costly than a short one. In the absence of any definite knowledge of the depth of shafts, or of the stratification of the rock through which the five-mile tunnel is to pass, we may content ourselves with the above estimate as reasonably accurate.

As corroborative evidence that this estimate is not too small, I would state that the published estimate of the cost of the summit-tunnel on the James River and Kanawha line, 7.8 miles long, is $13,253,310. This last tunnel has a section of 52 by 34½ feet, being 46 feet wide at water-line and 7 feet deep. It is, therefore, about 70 per cent. larger than the tunnel proposed by Colonel Sedgwick.

WESTERN TERMINUS OF CANAL.

At present there is slack-water on the Monongahela to and above the mouth of the Youghiogheny. The terminus of the canal should be at this slack-water. An effort is being made to slack-water the Youghiogheny to West Newton, or higher, for the benefit of the coal-mines on this river. Although this may answer the wants of coal-operators, who can only ship coal when there is a sufficiency of water in the Ohio, at which time there is usually good water in the tributaries, it cannot be depended on as the terminus of a canal doing a large business. The Youghiogheny, in dry seasons, does not supply enough water to provide lockage for an extensive navigation, and there is sometimes trouble even on the Monongahela. The terminus of the Chesapeake and Ohio Canal should therefore be at McKeesport.

As Colonel Sedgwick has stopped his estimate at Connellsville, it is necessary to increase it by the cost of extending the canal to McKeesport. The distance from Connellsville to McKeesport is forty-four miles, and the lockage in this distance is put by the board at 152 feet. In continuing the canal to Pittsburg they have an additional lockage of thirty-five feet. As their canal was assumed to be 5 feet in depth, and as all their levels refer to the bottom of the canal, the latter must have been taken at McKeesport at an elevation of 30 feet above low water in the Ohio at Pittsburg. Between Pittsburg and McKeesport there are two dams across the Monongahela, each of which has a lift of 8 feet. The bottom of the canal at McKeesport must therefore be 14 feet above the surface of the Monongahela at the same place, and the lockage to be provided for must be 19 feet. The increase in length of canal over Colonel Sedgwick's estimate will therefore be forty-four miles, and the increase in lockage 171 feet.

The Board's estimate of cost from Connellsville to McKeesport was $2,047,996. Increasing this by 25 per cent. it becomes $2,559,995, and adding the cost of the three additional locks, ($45,000 more,) we find the total cost of this section $2,605,000. If we allow 10 per cent. for contingencies the estimate becomes $2,865,500. This would make Colonel Sedgwick's total estimate for a canal, 33 feet wide at bottom, 48 feet wide at water-line, and 5 feet deep, and extending from Cumberland, Md., to McKeesport, Pa., a distance of one hundred seventy-one and a half miles, $23,133,585.

SIZE OF CANAL.

The depth which Colonel Sedgwick has chosen for the canal seems to me to be inadequate to the wants of a great through water-route. I think that on no account should the extension have a less size than the canal as now built to Cumberland; otherwise the sums expended below Cumberland in providing 6 feet of water will have been wasted as far as through-traffic is concerned. The chief objection to increasing the depth of the canal comes from the increased supply of water required to keep up the levels. The increased waste in a deep canal is due to the increased filtration through the soil, and the increased leakage through gates, both of which increases are due to the greater pressure exerted by the deeper water. If the calculations of those who examined and reported on the water-supply are to be trusted, there certainly seems to be enough water available to supply a 6-foot canal, if made reasonably tight.

There seems to be no doubt that a 6-foot canal can be kept up throughout all but the summit-level without any unusual expense. If, then, special care be taken in the construction of the summit-level, so that a 6-foot canal shall hold water as well as a 5-foot one usually does, there will be no lack of water, and a slight increase in expenditure will insure a far greater increase in the usefulness of the work. If the canal can only give 5 feet depth of water its utility will hardly be sufficient to justify its construction.

The only survey which we could make was so hurried, and the quantities to be used in calculation so uncertain, that it seems hardly worth while to attempt to estimate in detail how much the estimate should be increased to provide for a 6-foot extension. If a section were assumed the same as that of the present canal at Cumberland, the water area would be increased from 202½ square feet (as assumed by the Board for a 5-foot canal) to 252 square feet. This is an increase of 24½ per cent. Therefore, roughly assuming a corresponding increase of expenditure, we find the cost of a canal 30 feet wide at bottom, 54 feet wide at water-line, 6 feet deep, and extending from Cumberland to McKeesport, one hundred and seventy-one and one-half miles, $28,801,313. I think that this estimate is as fair an approximation as our limited information will now permit.

WORKING OF SUMMIT-TUNNEL.

I am decidedly of the opinion that the summit-tunnel should be worked by steam. The summit-tunnel on the Burgundy Canal in France is successfully operated by steam tugs, towing by the use of a submerged cable. They work very economically, and in fact this system is very generally used in France on their canalized rivers. To avoid smoke, which would be very objectionable in very long tunnels, it might be practicable to carry large reservoirs of steam, supplied from boilers at each end of the tunnel, as I understand is now done in New Orleans on one of the street-car lines. The omission of the tow-path saves a very considerable sum in the cost of the tunnel, and even in case of accident to a tug there would be no difficulty in poling the boats out of the tunnel.

INCLINED PLANES.

Where locks have to be so close together, as will undoubtedly be necessary at many places on this extension, I think that it would be in every way advantageous to resort to the system of inclined planes so successfully used on the Morris and Essex Canal. I am informed that, by this system, boats travel up and down the inclines as fast as they do on a level, and thus one of the greatest objections to a heavy amount of lockage is entirely obviated. Colonel Sedgwick has nearly finished a paper on this subject, which I will forward when completed, and which I request may subsequently be attached to this report. If the Wills Creek route should prove to be still available, I believe that its heavy ascending grade going west will make it necessary to use inclines instead of locks, at least immediately east of the summit. Boats would have to be in two parts to accommodate themselves to this arrangement. There are probably other places on the line where the same construction would be useful.

WESTERN CONNECTIONS.

It must be borne in mind that both this canal and the James River and Kanawha will utterly fail to become great through-routes of water transportation to the seaboard, unless the Ohio River is made to give a depth of at least 6 feet throughout the summer and fall, the time when the canals are doing their heaviest business, but the rivers are at their lowest. It is foreign to the present report to do more than allude to this matter, but as it is a vital one I think it proper, as the engineer in charge of the Ohio, to state that there is no practical difficulty in the way of securing this depth throughout the year by movable dams. For details reference is made to Ex. Doc. No. 127, House of Representatives, Forty-third Congress, first session. I have no hesitation in saying that it is impracticable to secure such a depth for navigation, at least above the falls, by any attempted guiding and controlling of the natural currents, however simple such operations may appear in the office. They have been repeatedly tried and found wanting. Below Pittsburgh the Ohio is often down to 12 inches, and between Louisville and Cairo it is not unfrequently down to 20 inches. For a fuller statement on the practicability of improving the navigation of the Ohio below the falls, see Ex. Doc. 127, Part 3, House of Representatives, Forty-third Congress, first session.

COMMERCIAL ADVANTAGES OF THIS CANAL.

This is a matter that I thought of working up, and for that purpose I had some statistics prepared from the last census-tables, but I have concluded that until a definite line of canal is selected, and a fair approximation of its cost is made, it will not be practicable to make a useful comparison with other through-routes. Until the profile of the canal is determined its equated length cannot be obtained, and this alone gives a basis of comparison. If this investigation is continued I will endeavor in my next report (should the survey be again confided to me) to take up this branch of the subject. In order to have a graphic comparison between this water-line, the Erie, and the James River and Kanawha, I have prepared a profile-sheet which shows each line. They all end at tide-water, the Erie beginning at Buffalo, the Chesapeake and Ohio at Pittsburgh, and the James River and Kanawha at Point Pleasant. The profiles show very clearly the immense natural advantages of the route occupied by the Erie Canal.

CONCLUSION.

In concluding this report I would recommend, as I have mentioned before, that if this investigation is to be continued careful surveys should be made by the Wills Creek route from Cumberland to McKeesport. This would require three independent parties under the control of one chief. One party should take the line from Cumberland to Meyer's Mills, and the other two should divide the distance from Meyer's Mills to Connellsville. From the latter place to McKeesport the route is unquestionably feasible, and the old surveys will do until the work of construction on the mountain section is well under way. The entire route should be surveyed with a special view to the use of inclined planes on difficult ground, and to the location of the necessary reservoirs; for reservoirs will be needed along the whole of the line. I would not recommend any survey at present of the Savage River route. It will be time enough to take that up if it is found impracticable to get a line through by way of Will's Creek. A saving in distance of twenty-nine and a half miles, and in lockage of 256 feet, is equivalent to a saving in time of about fourteen hours, which is so great a gain as to justify a large increase of expenditure in order to secure it. The cost of the surveys recommended would be about $20,000, and this appropriation I would recommend if this extension is to be carried through.

Respectfully submitted.

WM. E. MERRILL,
Major of Engineers.

General A. A. HUMPHREYS,
Chief of Engineers.

Report of Mr. Thomas S Sedgwick, Assistant Engineer.

WASHINGTON, D. C., *January* 30, 1874.

COLONEL: I have the honor to make the following report of instrumental reconnaissance and examination for the extension of the Chesapeake and Ohio Canal.

The western terminus of the canal is at Cumberland, Md., and the problem of its extension is a difficult one, arising not only from the great elevation to be overcome and the steep eastern slope of the Alleghany Mountains to be climbed, but also from the changed condition controlling the extension now as compared with those existing when the construction of the canal was begun in 1828. The route by Will's Creek and Flaugherty Creek to Meyer's Mills, on Castleman River, and thence by Castleman River and the Youghiogheny and Monongahela Rivers to Pittsburg, then believed, and, in fact, fully demonstrated, to be the best and most practicable route between Cumberland and Pittsburg, is now occupied and controlled throughout its entire length by the Pittsburg branch of the Baltimore and Ohio Railroad; so that portion of the route between Cumberland and the summit of the mountain at Sand-Patch tunnel is not now practicable for the location and construction of a canal, there being also a second railroad (the Pennsylvania and Cumberland) between Cumberland and the mouth of Little Will's Creek, fifteen miles, so that the hope of the extension of the canal reasonably reverts to the Deep Creek route, the alternative route with the Will's Creek route, both which were reported on in detail by the Board of Internal Improvements in 1826.

This route follows the North Branch of the Potomac to the mouth of Savage River, and thence by the Savage River and Crabtree Creek to Bear Creek and Deep Creek, and by the Youghiogheny to the junction with Castleman River, at Turkey Foot, now confluence, a point common to the two routes.

This route is eighteen miles longer than the Will's Creek route, and its summit-level was taken 440 feet higher than the summit-level of the Will's Creek route. That portion of the route between Cumberland and the mouth of Savage River is occupied in general by the main line of the Baltimore and Ohio Railroad, but, the valley being wide and open and the railroad company having been directed by process of law to respect the prior location of the canal, which had been made as far as the mouth of Savage River, the conditions are not materially changed with regard to the location and construction of a canal between those places, excepting, probably, in the matter of land and right of way.

The favorable condition of the Will's Creek route being so disadvantageously modified by railroad occupation, the question arose as to the probability of the existence of a route between the Will's Creek and Deep Creek routes, which could have a lower summit-level than the Deep Creek route, and which could be supplied with water from the reservoirs on Castleman River designed for the Will's Creek route, and at the same time would have a summit-tunnel of a feasible length. In accordance with these considerations it was deemed advisable, with your approval, to thoroughly examine the summit-passes between the Savage and Castleman Rivers, a region not heretofore surveyed, and to determine their character and conditions with reference to the extension of the canal thereby. Accordingly a route, beginning at the mouth of Savage River, the termination of the previous surveys, and following the Savage to Blue Lick Run, crossing the summit of the mountains near the Shades, on the old National road, and descending to the Castleman River at Salisbury, Pa., by Piney Run, was examined by instrumental survey.

This route was found to be generally favorable, especially as to the matter of a good location and cost of construction of a line of canal, though not so favorable as to the summit-tunnel. It traverses a very important and valuable coal-basin, and would provide an additional transportation outlet for the Cumberland coal-basin and enhance the agricultural growth of the valley of the North Branch and its larger tributaries. This route is longer than the Will's Creek route, but is better conditioned as to the distribution of locks and efficiency and economy of the water-supply.

THE CONDUCT OF THE SURVEY AND CHARACTERISTIC FEATURES OF THE ROUTE.

The surveying party rendezvoused at Bloomington, W. Va., near the mouth of Savage River, on the 25th of July, but owing to some delay in procuring a cook, and the slow arrival of the surveying instruments, surveying operations were not begun until August 1. The survey was begun at the junction of Savage River and the North Branch, which comes some forty miles from the southwest, runs northeasterly some thirty miles to Cumberland.

The elevation was taken to be 960 feet above tide-water at Georgetown, D. C., as determined by the surveys of 1828. This elevation corresponds with the grade-notes of the Baltimore and Ohio Railroad.

The Savage River, from its mouth to Crabtree Creek, five and a quarter miles, has a general direction west-northwest, its bed rising uniformly at the rate of 74 feet per mile. In this distance it has worn its way through and right across the axis of Savage Mountain (which lies northeast and southwest) to the depth of nearly 1,000 feet, consequently the channel is crooked, and has rough, rocky bluffs at the bends, and is the most unfavorable portion of the route in regard to location and construction. The Baltimore and Ohio Railroad holds its way high up on the southern side of the ravine, to gain the summit of the mountain at the head of Crabtree Creek. The valley is unsettled and wild, and covered with a rank growth of laurel, so that the line of the survey often followed the bed of the stream.

A gauging of the river just above its mouth gave a discharge of 18 cubic feet per second.

From Crabtree to Monroe Run, two and a half miles, the river turns sharply to the north, its bed rising at the rate of 53¾ feet per mile; the valley grows wider and has no bluff or rocky banks; thence to Blue Lick Run the direction is north-northeast for five and three-quarter miles; and thence to the summit of the mountain by Blue Lick, five and three-quarter miles, the direction is north, with a convex bend to the east.

From the mouth of Crabtree the Savage River lies between the Savage Mountain on the east and the main Alleghany on the west, with a general direction north-northeast reaching some sixteen or eighteen miles, crossing the National road some four miles west from Frostburg, Md. From the mouth of Crabtree Creek to Chaney's Mill, on Blue Lick, near its head, the valley is wide and open, and has often several hundred yards width of bottom-lands; the river is without bluffs or rocky banks, and rising at the rate of 65 feet per mile. The general character of this section of the route is very favorable for the construction of a canal, there being room enough for a good location, and the hill-slopes having terraces favorable for supporting the levels of the canal to suitable sites for locks. A location can be made on the west side of the valley over this section, without difficulty or obstacles, to a point where the entrance to the summit-tunnel may be satisfactorily located.

From the summit of the mountain along Two-Mile Run to Piney Run, a distance of four miles, the direction is northeast, and thence along Piney Run to its junction with Castleman River, one mile north of Salisbury, Somerset County, Pa., the direction is north-northwest, and the distance is six and one-quarter miles, the ground falling at the rate of 79.4 feet per mile. Along Two-Mile Run, which crosses the National road at Shades, the same difficulty in surveying was met as on the first section of Savage River, and also as far down Piney as Ingle's Mill, within one mile of its mouth. From Ingle's Mill to the mouth of Piney the character of the valley is very favorable for location and construction on either side of the valley, being wide and open, with much bottom-land and meadow.

The survey having demonstrated the practicability of this route, the examination might have closed when the valley of Castleman River was reached; but, for the purpose of making a more complete comparison of this route with the Will's Creek route, the survey was continued down the valley of Castleman River to Meyer's Mills, (Meyer's Dale City,) at the mouth of Flaugherty Creek, and thence to Blue Lick, these being the valleys into which the proposed tunnels led from Bowman's Run on Will's Creek. From Piney Run to Flaugherty Creek, a distance of six and a quarter miles, the river has several great bends, making a very crooked route, with a general direction nearly north, descending at the rate of 7½ feet per mile.

For the purpose of making close connections with the surveys of 1824 and 1828, and to aid in the identification of prominent points of those surveys, lines were surveyed three miles up Flaugherty Creek, and one and a half miles up Blue Lick. A benchmark was pointed out and identified as one made by the surveying party of 1828, under the direction of Nathan S. Roberts, chief engineer of the board of engineers of the Chesapeake and Ohio Canal. This bench was marked 1828, and under this was 1,972, the latter being the elevation of the summit-level above the tide at Georgetown. Our levels agreed with this elevation within one foot.

In addition to these examinations, a survey was made of the portion of Savage River above Blue Lick, and to the same summit by way of Mud Lick Run, the most difficult part of our work. This route was so very crooked and so much longer than the Blue Lick route, that it is not at all taken into consideration.

The whole distance thus surveyed was fifty-three miles, closing with the 1st of October. The distances here given are those made in the chaining of the survey in tracing the streams, and are greater than given in the approximate location for the canal for the purposes of estimating the cost. One-half the surveying party was dismissed on the 1st of October at Dale City. Returning to Salisbury, the valley of Castleman River was examined instrumentally as far up as Pleucher's Narrows, the site of one of the reservoirs proposed in connection with the summit of the Will's Creek route; and Meadow Run, a tributary of Castleman River, coming in from the east just above Salisbury, was traced for a distance of two miles.

The surveying operations were closed here on the 14th of October, over sixty miles of line having been surveyed and leveled in two and one-half months.

The valley of Castleman River, above Salisbury, is a fine, open, agricultural valley, thickly-settled, but not so rich and well-cultivated as the portion between Salisbury and Meyer's Dale City.

Taking with me two assistants, I made a reconnoissance of the headwaters of the North Branch, examining the river from Fairfax's stone, the southwest boundary-corner of the State of Maryland, to the crossing of the Northwestern Turnpike and Ryan's Glade Run, a distance of some fifteen miles, in which distance the river falls at the rate of 20 feet per mile. Thence to Bloomington, some twenty-eight miles, the fall is between 40 and 50 feet per mile. I had intended making an examination of the Black Water Fork of Cheat River, which is just over the mountain from the North Branch, but a snow storm of eight inches depth on the 20th October prevented the carrying out this intention, and the remaining assistants were dismissed.

The valley of the North Branch is quite favorable for canal construction except in the rapidity of its rise.

During the time of our surveying operations the streams were at their lowest stages, and excellent opportunities were afforded for determining their minimum of supply. Several gauges of Savage River and Piney Run were made; also of Castleman River at Pleucher's Narrows.

Mr. C. L. Fulton, assistant engineer, rendered efficient services as transmit-man and in conduct of the surveying party, and Mr. Fred. W. Frost, civil engineer, was a competent and energetic leveler; and in fact all the gentlemen of the party rendered most efficient services, under untoward circumstances of bad weather, with becoming promptness and energy.

HISTORY OF FORMER SURVEYS.

The first authoritative move toward a system of national internal improvements was made in April, 1824, when Congress passed an act authorizing the President "to cause the necessary surveys, plans, and estimates to be made of the routes of such roads and canals as he may deem of national importance in a commercial or military point of view, or necessary for the transportation of the public mail, and to employ two or more skillful engineers and such officers of the Corps of Engineers as he may think proper to carry this act into effect."

In pursuance of this act, the then Secretary of War, John C. Calhoun, constituted a Board of Engineers, consisting of General Bernard, Corps of Engineers, Lieutenant-Colonel Totten, Corps of Engineers, and John L. Sullivan, civil engineer, who entered at once upon their duties, being assisted by many officers of the Army detailed for this purpose.

The Board made very complete surveys and reports on routes for the Chesapeake and

Ohio Canal, the Ohio and Erie Canal (since known as the Sandy and Beaver Canal) in Ohio; Ohio and Schuylkill Canal, (now the well-known Pennsylvania Canal;) Delaware and Raritan Canal; James River and Kanawha Canal, and many other routes for canals and roads.

The first examinations and surveys of a route for a canal to connect the Chesapeake Bay and the Ohio River, by the valley of the Potomac, on the eastern, and the Youghiogheny and Monongahela Valleys on the western, slopes of the Alleghany Mountains, were made in the summer of 1824, and were chiefly to determine the practicability of the undertaking, and were almost entirely restricted to the examination of the mountain or summit section between Cumberland, on the North Branch of the Potomac, and the junction of Youghiogheny and Castleman Rivers, at Turkey Foot.

The route thus surveyed in 1824 was by the North Branch of the Potomac to the mouth of Savage River, and by Savage River, Crabtree Creek, and a branch of Crabtree Creek to Bear Creek and Deep Creek, and thence by the Youghiogheny to Turkey Foot. That part of the route from Cumberland to the mouth of Savage River was surveyed by Maj. J. J. Abert, Topographical Engineers, and the remaining portion by Capt. William G. McNeill, Topographical Engineers.

The Baltimore and Ohio Railroad now occupies a portion of this route from Cumberland, but in ascending the mountain it diverges to the south, its summit being about eight miles south of the summit of the canal-route.

Several summit-crossings were surveyed, and careful gaugings were made of the streams most available for furnishing water for the summit-level, and an elaborate report was prepared by the Board of Engineers. They considered the route practicable with summit-tunnels from one and a third to five and a half miles in length, although the sum of the lockages between Georgetown and Pittsburg was 3,837 feet, which exceeded anything that up to that time had been deemed feasible. The summit-level was found to be 2,408 feet above tide. It was to be supplied with water by means of large reservoirs to be constructed on the Youghiogheny River, at the point where it is now crossed by the route of the Baltimore and Ohio Railroad.

(See Appendix A.)

During the next year a more careful and detailed survey was made " to determine the route to be recommended, as also to obtain the data necessary to frame a general plan of the work and a preparatory estimate of the expense." The report of this year (1826) was more complete than the former one, and discussed the character and general features of another route—that by the valley of Will's Creek, leading northerly and easterly from Cumberland, and crossing the mountains to the valley of Flaugherty Creek, which empties at Meyer's Mill into Castleman River, a branch of the Youghiogheny River, which it joins at Turkey Foot, near Confluence. The summit-level of this route was placed 440 feet lower than the summit-level of the Deep Creek route, with a tunnel four miles long. The distance by the Will's Creek line is eighteen miles shorter between Cumberland and Turkey Foot than by the Deep Creek line.

The supply of water for the summit-level was to be provided by two reservoirs on Castleman River, the lower one at Forney's Mill, one mile below Salisbury and six miles from the west end of the tunnel-level, and the upper one at Pleucher's farm, about five miles above Salisbury and about six miles above the one at Forney's Mill, with which it was to be connected by a feeder. The water-supply was deemed to be more abundant than on the Deep Creek route.

A survey was also made with a view to connect the reservoirs of the Deep Creek route with those of the Will's Creek route. This would necessitate a feeder of twenty-five miles in length to reach Pleucher's farm, with one tunnel two miles long, and another five miles long and otherwise very expensive. This plan, however, was deemed feasible.

The report of 1826 was remarkable in that it gave a careful analysis of prices and probable costs, based on units of labor, of men and horses, and on the cost of producing lime, procuring stone, doing earth-work, obtaining transportation, &c., and these estimates were given for the separate divisions or sections of the proposed canal.

A carefully-prepared estimate was given in detail for characteristic sections of the work, varying from 300 yards to 15,000 yards in length.

The dimensions of the proposed canal were 48 feet width at top water-line, 33 feet at bottom, and 5 feet depth of water.

The section from Georgetown to Cumberland (one hundred and eighty-six miles) was estimated to cost	$8,177,081
From Cumberland to Turkey Foot, (seventy and six-tenths miles)	10,028,123
From Turkey Foot to Pittsburgh, (eighty-five and one-quarter miles)	4,170,224
Giving an estimated total cost of	22,375,428

This estimate of cost was so much greater than had been anticipated that all intentions of carrying out the enterprise were suspended.

The canal company was, however, granted a charter, and a convention was called to consider the conditions controlling the enterprise, and, among other actions taken, they appointed a committee to revise the estimates of the Board of Internal Improvements. This committee met at Washington in December, 1826, and on the most reliable information they could command, and based upon the cost and contract-prices of similar works then in progress, they estimated the cost of the entire canal from Georgetown to Pittsburg at $10,000,000. The estimates of the Board were severely criticised as being very erroneous, and the then President of the United States, John Quincy Adams, was influenced to appoint a commission of civil engineers to examine the two sets of estimates and reconcile them. Messrs. James Geddes and Nathan S. Roberts, civil engineers of high repute, were appointed to that duty, and reported in 1828. They made the estimated cost of the canal from Georgetown to Cumberland, on the same scale of dimensions as proposed by General Bernard, $4,330,992, whereas the Board's estimate for the same service was $8,177,081. This section was completed in October, 1850, at a cost of $11,071,176. Augmenting General Bernard's estimate by cost of lands for right of way, engineer expenses, damages, and salaries of officers, there was yet a difference of $2,087,816 over General Bernard's estimate, an increase of 25 per cent., but it is proper to state that the canal as built from Georgetown to Harper's Ferry, a distance of sixty miles, is 60 feet wide at water-line, 42 feet at bottom, and is 6 feet deep; from Harper's Ferry for a distance of forty-five miles it is 50 feet wide at water-line and 32 feet at the bottom; and thence to Cumberland, seventy-seven and one-half miles, it is 54 feet at top and 30 feet at bottom. The depth throughout its whole length is 6 feet. The locks are 100 feet long, 15 feet wide, with an average lift of 8 feet, and they will pass boats of 120 tons capacity. Some difference should also be allowed in favor of General Bernard's estimate for the increase in the value of money and of labor from 1824 to 1850.

I have been thus particular in reciting the history of these estimates because that portion of them relating to the cost of the canal from Cumberland to Pittsburg must at present be taken to give an approximate cost of the proposed extension of the canal proper, reasonable additions being made to them for right of way, engineering expenses, and salaries, &c.; and it is, therefore, important to show their general correctness.

Messrs. Roberts and Cruger also made a location of the canal from Cumberland to Pittsburg in 1828, following almost exactly the leading features of the plan proposed by the Board of Internal Improvements, as to route, plans for reservoirs, &c., excepting only that they passed the summit by a tunnel from the same point on Bowman's Run to a point on Blue Lick Creek, instead of Flaugherty. Their estimate of the section from Cumberland to Pittsburgh was $7,732,661, while that of the Board of Engineers was $14,198,346.

WATER-SUPPLY.

The quantity of water needed to operate the canal is dependent on its character and dimensions, the size and lift of its locks, and the daily tonnage to be accommodated; and if the canal have a summit-level, we must consider its character and the length of canal on each side of the summit, which must be supplied therefrom.

The continual losses by surface evaporation, filtration, absorption, and waste at weirs and aqueducts, must also be supplied. All these sources of loss, except that by evaporation, can be reduced to reasonably small quantities by careful construction.

If we use the dimensions recommended by the Board of Internal Improvements, we get a surface width of 48 feet, and locks 100 feet long, 15 feet wide, and 8 feet lift. These locks are adapted to the use of boats of 120 tons burden. [The average tonnage of the canal-boats now in use on the Chesapeake and Ohio Canal is about 112 tons.]

Boats passing alternately up and down through the locks can be passed at the rate of one boat in each eight minutes, or, say, seven per hour, or one hundred and sixty-eight per day of twenty-four hours, which is equal to a daily tonnage of 20,160 tons, or an annual tonnage of 6,148,800 tons for ten months of the year, the probable navigable season on this route. [The greatest number of boats passed through one lock in one day on the Erie Canal was 170 in 1862.]

The summit-level of this route is taken at an elevation of 2,100 feet above tide. Cumberland has an elevation of 603 feet, and the mouth of Savage River 960 feet above tide, while the Castleman River, at the mouth of Piney Run, has an elevation of 1,990 feet above tide.

Castleman River is a large stream amply sufficient to feed the canal westward from the summit. The ascent from the mouth of Savage River to the summit is at the rate of 65 feet per mile, and the tunnel is designed to pierce the mountains at an elevation about 100 feet higher than the mouth of Piney Run. There is not a sufficiency of water to feed the canal on the eastern slope of the mountain, above the mouth of Savage River, and a portion of the canal must be supplied from the summit-level.

We will now examine the conditions of loss and supply of the section east of the summit, with a view to determine how much loss must needs be supplied from the summit-level.

The section from Cumberland to Savage River, thirty-one miles in length, can certainly be supplied from the daily discharge of the North Branch and Savage River Allowing the daily loss by evaporation, filtration, and absorption and waste at weirs to amount to three inches per day for each square foot of surface, we find a daily loss on this section of 1,964,160 cubic feet, (5,280 by 31 by 48 by ¼,) 2,273 cubic feet per second. No account has been taken of the leaking and spill at locks, as these quantities may be considered as the same at each lock, and this water merely passes from one level to another in the same manner as the prism of lift, without loss to the canal.

Several gaugings of Savage River, near its mouth, gave an average discharge of 18 cubic feet per second, and north branch was estimated to deliver at least three times as much more, or 54 cubic feet per second, making an available supply of 72 cubic feet per second, or more than three times the estimated quantity required.

These estimated losses of water are taken for a well-made, puddled canal of favorable conditions. A new canal during the first year or two would probably lose twice this quantity per day; and if the canal were occupied by active transportation the agitation caused thereby would slightly increase the loss by evaporation and waste; however, these causes cannot have a maximum effect except when the canal is well filled with water. No account is taken of the lockage at present, because the prism of lift-water passes from level to level like the spill and leakage at the locks. If provision be made for feeding the canal at one or two other points before reaching Cumberland—say at half way—then the loss to be supplied at the mouth of Savage River would be but one-half that stated above, or 982,100 cubic feet, less than 12 cubic feet per second, and only two-thirds of the quantity of water discharged by Savage River alone.

The summit-level is at a distance of sixteen miles from the mouth of Savage River. the ascent being 1,140 feet, and therefore requiring 143 locks of 8-foot lift, or 114 locks of 10-foot lift.

The daily loss from evaporation on this section would, in accordance with the above data, be less than 12 cubic feet per second. There is no other available constant supply of water east of the summit for this section than the Savage River, which in August last gauged but 6 cubic feet per second at the mouth of Blue Lick. To supply the remaining 6 cubic feet per second—518,400 cubic feet per day—during the months of July, August, and September, will require a reservoir-capacity of about 52,600,000 cubic feet, including a loss by evaporation of one-quarter of an inch per day on reservoirs of 15 feet depth, without regard to either steady or periodical influx during that time. The available places for reservoirs are the valleys of Crabtree Creek, Monroe Run, Poplar Lick Run, and the Savage River, above the mouth of Blue Lick Run. Allotting one-fifth of this quantity (say 10,500,000 cubic feet) to each of the three first-named places, we find that these reservoirs must be 1,800 feet long, 500 feet wide, and must average 12 feet in depth. Allotting to the Savage River the remaining two-fifths of the quantity to be stored, or 21,000,000 cubic feet, we must provide a reservoir 2,500 feet long by 560 feet wide, averaging 15 feet in depth. This can readily be done. A much larger reservoir can be provided on the Upper Savage than is herein required, the valley being very favorable in its topography, as was developed by our survey. That these reservoirs would be filled in the spring months is beyond doubt, as an influx of 4 cubic feet per second would fill either of the smaller ones in thirty days, and the larger one in double that time; and all these streams deliver from 10 to 20 cubic feet per second in March or April, when the snows are melting; while only two-fifths of a cubic foot per second is needed to replace the evaporation on one of the smaller reservoirs.

We come now to consider the summit-level with a tunnel of five miles in length, and a basin at each end one-half a mile long and 32 feet wide, the tunnel itself having 32 feet width of water. The evaporation in the tunnel may be taken as nothing, as in fact there is always an infiltration at tunnels that may be utilized in this case, and assuming that the tunnel may be brick-lined, we need only consider the loss by evaporation, &c., on the two basins, or open portions, and that by leakage and spill at the locks at each end of this level. The latter may be taken at 1,000 cubic feet per hour at each lock. Assuming, as before, the daily loss by evaporation, absorption, and filtration at 3 inches of depth per day, we obtain for one mile of canal a loss of 42,240 cubic feet per day, which, increased by 48,000 cubic feet for loss at locks, gives a total waste on the summit-level of 90,240 cubic feet per day. But the loss from evaporation, &c., between the tunnel and the mouth of Piney Run on the west, and the mouth of Blue Lick on the east, a total distance of nine and a half miles, must also be supplied from the summit-level, and this causes an additional daily loss of 601,920 cubic feet, making a total daily loss, which must be made good, of 692,160 cubic feet per day.

To determine the quantity of water drawn from the summit-level by lockage, we must assume that a certain number of boats will pass the summit daily. If boats follow each other in the same direction over a summit-level, each will take from this level two lockfuls of water; but if they alternate uniformly, boat with boat, then each boat draws off but one lockful of water. For the purposes of this estimate, we will assume that two-thirds of the boats passing daily are going in the same direction, and the other third in the contrary direction, and thus each boat may be charged as drawing off one and a half lockfuls each, equal to 18,000 cubic feet.

We will for the present consider the daily tonnage to equal 100 boats per day, requiring 1,800,000 cubic feet of water for lockage daily, to which add the daily loss from evaporation, absorption, filtration, and leakage heretofore found, (672,160 cubic feet,) and we have a total daily loss on the summit-level of 2,492,160 cubic feet, or 28.8 cubic feet per second.

The only available source of supply for feeding this summit-level is Castleman River, into whose valley the tunnel opens. The elevation of the summit-level has been taken with special reference to obtaining the necessary feed-water from the Pleucher reservoir on Castleman River, which was originally designed for the Will's Creek route. The average supply or discharge of the river is greater than the quantity required, as the following gauging will show:

	Cubic feet.
June 21, 1825, at Pleucher's, per second	18
July 10, 1825, below Flaugherty, per second	38
July 12, 1825, mouth Flaugherty, per second	46
March 21, 1825, at Pleucher's, per second	98
March 21, 1825, below mouth of Piney, per second	536

At the time of our survey a gauging of the river at Pleucher's Narrows gave 25 cubic feet per second.

Taking the same capacity of reservoirs as that proposed by the Board of Internal Improvements, namely, 126,333,780 cubic feet, this amount would be furnished in fifteen days, according to the gauging of March 21. If we assume that only half of this daily supply could be expected, we yet find that the reservoir could be filled in any one of the spring months.

This reservoir was stated to have a surface-area of 9,365,400 square feet, from which the daily evaporation, at a rate of one-fourth of an inch per day, would be 195,120 cubic feet, giving the total daily consumption and loss as follows:

	Cubic feet.
Lockage of 100 boats	1,800,000
Evaporation, &c., summit-level	90,240
Evaporation, &c., on 9¼ miles of canal	601,920
Total daily consumption	2,582,160

This is at the average rate of 31 cubic feet per second. It may be safely assumed that this daily consumption would be met by the average daily discharge of the river, except during the months of July, August, and September, but during these months the natural flow, at a rate of 18 cubic feet per second, the lowest gauging given would put into the reservoir 1,555,200 cubic feet per day, leaving only 1,133,440 cubic feet to be supplied from the previous accumulations. At this rate the reservoir would not be emptied in less than one hundred and eleven days, or in four months less nine days, even if there should be no rain-fall during the months named.

In addition to this supply, a reservoir is practicable on Meadow Run, and another, of a probable capacity of 25,000,000 cubic feet, on Piney Run, which has a supply of 3 feet per second at Findlay's Mill during the average summer discharge. Assuming for the Meadow Creek reservoir an equal capacity and a depth of 10 feet in each, the loss by evaporation would be for both 104,200 cubic feet per day, and the influx (allowing only 2 feet per second for Meadow Run) 432,000 cubic feet per day.

The Meadow Run feeder would probably be about one mile in length, and the Piney Run feeder about three and one-half miles. Assuming each feeder to have a width of 20 feet, we thus have a total feeder-surface for these two reservoirs of four and one-half miles in length and 20 feet in width. According to our previous allowance of 3 inches vertical on each square foot for losses by all causes, we have a total daily loss on these two feeders of 118,800 cubic feet.

We would thus have a storage-capacity of 176,333,780 cubic feet, and a daily flow into the reservoirs of 1,987,200 cubic feet. On the other hand, we have a daily consumption on the canal of 2,582,160 cubic feet, and a daily loss on reservoirs and feeders of 418,120 cubic feet. The daily drain on the supply stored would therefore be 1,013,080 cubic feet, which would not exhaust them in less than 174 days, or about six months. If the total influx were but 12½ cubic feet per second, the reservoir would last 92 days, even should the canal be worked to its maximum capacity throughout the driest season of the year, conditions that seldom occur and act conjointly for the whole season of the three dry months. Any less amount of business than has been assumed, (equal to 3,600,000 tons during a navigation season of ten months, and the tonnage of the Erie Canal is given as 3,562,500 tons for 1872,) or any rain-fall during the months named, renders more certain the adequacy of the supply; and only the careless construction of the canal and its appurtenances, or an increase of business over that supposed, or a more protracted drought than has ever been known in this region, can render the supply inadequate.

The data used for evaporation, absorption, and filtration and waste, are the averages of the best authorities, and they are 50 per cent. greater than are taken for the canals of Great Britain.

If we consider the summit-supply as dependent on the average annual rain-fall and the catchment-basins, we find that the catchment-basin of the Pleucher reservoir is very nearly twelve miles long and five miles wide, and has an area of sixty square miles. The average annual rain-fall at Pittsburg, Pa., was 34.96 inches for eighteen years; at Marietta, Ohio, 41.58 inches for twenty-eight years; at Portsmouth, Ohio, 38.20 inches for fifteen years; at Carlisle, Pa., 34.00 inches for six years; and at Gettysburg, Pa., 38.80 inches for seven years. If we take an average of these as representing the annual rain-fall for the region under consideration, we get 38 inches per annum. Applying this to the catchment-area given, and assuming that but one-third of the quantity is caught by the reservoir, we have an annual quantity of 1,698,965,300 cubic feet, enough to fill the reservoir thirteen times; and the Piney Run reservoir, with a catchment-area of twelve square miles, would also be filled thirteen times; the total annual supply by rain-fall being 2,038,758,360 cubic feet, which gives an adequate supply for the use of the canal during a period of twenty-five months, with allowances for evaporation of reservoirs and loss in feeding.

Again, if we take an average of the gauging in March and June as representing the available rain-fall that will be caught by the Pleucher reservoir, we get 1,829,088,000 cubic feet as the annual supply; whereas the consumption for the uses of the canal would be for ten months 780,000,000 cubic feet, or only about 43 per cent. of the estimated supply. This estimate of consumption is twice as great as that assumed by the Board of Internal Improvements.

The changed conditions with reference to the Forney's Mill reservoir, considered essential to the supply of water for the Will's Creek route, renders it of doubtful present practicability. Its site is at the mouth of Piney Run, with a dam one-quarter of a mile below, and the height proposed would raise the water to a contour-line 30 feet above the present surface of the mill-dam at that place; would reach nearly one-fourth the distance to Pleucher's Narrows, and nearly a half mile up Piney Run; would flood the road from Salisbury toward Meyer's Dale City for a distance of half a mile, and would submerge the bridge of Livengood's Mill, and the one at the mouth of Piney Run; it would also cover the road and bridge toward Grantsville, about one mile of a graded railroad, to a depth of from 10 to 20 feet, two mills now in operation, a large area of valuable meadow farming-land, and a part of the surveyed site of the town of Salisbury.

A low dam now in use on this site, if made tight, would save the water-supply for feeding the canal below the mouth of Piney Run.

I have personally examined Castleman River to some distance above Pleucher's Narrows, and find that a reservoir of considerable capacity may be constructed at the crossing of the National road, about two miles above Pleucher's. That would be a very useful auxiliary for storing water for the summit-level, saving a portion of the drainage that in spring floods would waste over the Pleucher dam.

There is yet another source of supply for the summit-level on the Upper Savage at the crossing of the Lonaconing road, where the elevation of the stream is 2,180 feet at the distance of five and a half miles from the mouth of Blue Lick. The topography is very favorable for a large reservoir—say of a capacity of 80,000,000 cubic feet. Thus the summit supply would be increased by nearly 50 per cent., and furthermore provide an ample supply to replace the loss by evaporation on the fourteen-mile section from the summit-level to the mouth of Savage River. If reasonable expense were incurred in puddling or lining the feeders, with a view to reduce the loss in transmission of supply to a minimum, the supply of water would be sufficient for the most active business of the canal.

The tunnel enters the valley of Castleman immediately at the Pleucher reservoir, and there would not be any loss on feeding therefrom, but the feeders from Meadow Run and Piney Run, if brought to the summit-level, should probably be lined, but if fed into the canal at shorter distances they would not need to be lined.

ESTIMATE OF COST.

In making this estimate of cost I have adhered to the dimensions recommended by the Board of Internal Improvements in their report of 1826, viz: 48 feet width at water-line; 33 feet width at bottom, and 5 feet depth of water; locks 100 feet long, 15 feet wide, and of 8 feet lift; because reference must be had to the quantities of work to be done as estimated by them between Cumberland and the mouth of Savage River, and from Meyer's Mill to Pittsburg. These dimensions are very nearly the same as those of the completed canal between Harper's Ferry and Cumberland, a distance of one hundred and twenty-five miles, equal to two-thirds of the length of the finished canal.

Section from Cumberland to mouth of Savage River, length thirty-one miles, lockage 334 feet.

1,336,600 cubic yards excavation, earth, at 30 cents per yard	$400,980
300,000 cubic yards excavation, rock, at $1.25 per yard	375,000
1,300,000 cubic yards embankment, at 20 cents	260,000
200,000 cubic yards retaining wall, at $1.50	300,000
270,000 cubic yards puddling, at 10 cents extra	27,000
40 culverts, (arches,) at $2,000 each	80,000
42 locks, 8 feet lift, at $15,000 each	630,000
2 aqueducts, 120 feet and 210 feet, (wooden)	10,500
1,000 cubic yards aqueduct masonry, at $10	10,000
4 waste-weirs, $3,000 each	12,000
30 farm-bridges, at $450	13,500
5 miles grubbing and clearing	1,250
3 dams, at $3,000 each	9,000
400 acres land-damages, at $50	20,000
Special damages, water-powers	15,000
Engineering and superintendence	75,000
Sum of items	2,239,230
Contingencies, 10 per cent	223,923
Cost of thirty-one miles, averaging $79,456.55	2,463,153

These quantities are made from a comparison of those of the Board of Internal Improvements, and those of Messrs. Roberts and Cruger. Adding the items of farm-bridges, waste-weirs, land and special damages, and engineering superintendence, growing out of the changed conditions of then and now, the average cost per mile of this section, by the Board of Internal Improvements, was $59,476.

From the mouth of Savage River to Crabtree Creek, distance five and a half miles, lockage 388 feet.

150,000 cubic yards excavation, earth, at 30 cents	$45,000
50,000 cubic yards excavation, rock, at $1.20	60,000
80,000 cubic yards embankment, at 20 cents	16,000
10,560 cubic yards retaining wall, at $1.50	15,840
40,000 cubic yards puddling, at 10 cents extra	4,000
3 culverts, at $1,500 each	4,500
48 locks, at $13,500 each	648,000
1 aqueduct	3,000
900 cubic yards masonry, at $8	7,200
5 miles grubbing and clearing, at $300	1,500
Dam and feeder, Crabtree Creek	15,000
2 dams	3,000
Engineering and superintendence	12,500
Sum of items	835,540
Contingencies, 10 per cent	83,554
Cost of 5½ miles, averaging $167,108	919,094

The rock-excavation on this section is a sandstone stratum, and more cheaply worked, and being of a quality suitable for the required masonry, and close at hand, the masonry can be more cheaply done. The average cost is great; but there are nine locks per mile, making more than 70 per cent. of the cost.

From Crabtree Creek to summit-level, distance eleven miles, lockage 732 feet.

800,000 cubic yards excavation, earth, at 30 cents	$240,000
400,000 cubic yards embankment, at 20 cents	80,000
140,000 cubic yards puddling, at 10 cents extra	14,000
10 culverts, at $1,500 each	15,000
92 locks, at $13,500 each	1,242,000
10 miles grubbing and clearing	2,500

5 crossing-bridges, at $450	$2,250
5,000 cubic yards protection, at $1.25	6,250
2 reservoirs and feeders	20,000
1 reservoir and feeder	15,000
Engineering and superintendence	25,000
Sum of items	1,662,000
Contingencies, 10 per cent	166,200
Cost of 11 miles, averaging $166,200	1,828,200

On this section ninety-two locks make two-thirds of its cost. The reservoirs for Monroe Run, Poplar Lick, and the Upper Savage are included.

Summit-level, six and a half miles long.

This level comprises a tunnel five miles long and approach-basins each three-quarters of a mile long. The dimensions of the tunnel are given by a segmental circular section of 32 feet diameter, with a height of 26 feet from bottom of tunnel to crown of arch, providing a waste-way 25 feet on bottom, 6 feet deep and 32 feet on top, and a head-way of 20 feet; the lining to be of the best hard brick, with a thickness of 18 inches all around the section. Horizontal fenders are to be laid at water-line, to act as fenders for passing boats and to protect the brick-masonry from injury. The approaches are to give a top water-line of 32 feet and a bottom width of 25 feet, (in rock-cutting.)

No provision is made for a tow-path, because the additional cost of doing so, say $500,000, would, at 7 per cent. interest, maintain and operate five tug-boats, enough for the business of 100 boats per day.

870,000 cubic yards excavation, tunnel, at $5	$4,350,000
2,500 cubic yards excavation, shafts, at $5	12,500
81,000,000 brick, lining of tunnel, at $25 per thousand	2,025,000
600,000 brick, lining of shafts, at $25 per thousand	15,000
180,000 feet (board-measure) fenders, at $30 per thousand	5,640
200,000 cubic yards rock-excavation, approaches, at $1.25	250,000
20,000 cubic yards concrete filling about arch, at $10	200,000
10,000 cubic yards puddling, at 30 cents	3,000
44,000 cubic yards filling on top of arch, at $1	44,000
Engineering and superintendence, 5 years	50,000
Sum of items	6,955,140
Contingencies, 20 per cent	1,391,028
Cost of summit-level	8,346,168

From summit-level to he mouth of Piney, five and a quarter miles.

300,000 cubic yards excavation, earth, at 30 cents	$90,000
50,000 cubic yards excavation, rock, at $1.25	62,500
200,000 cubic yards embankment, at 20 cents	40,000
60,000 cubic yards puddling, at 10 cents extra	6,000
8 culverts, at $1,500 each	12,000
1 aqueduct over Piney Run	5,000
16 locks, at $15,000 each	240,000
450 cubic yards abutment-masonry, at $8	3,600
Grubbing and clearing	600
6 bridge-crossings, at $450	2,700
Land-damages	10,000
Engineering and superintendence	10,000
Sum of items	482,400
Contingencies, 10 per cent	48,240
Cost of 6½ miles, (averaging $81,636.90)	530,640

From mouth of Piney to Meyer's Mill, six and a quarter miles

200,000 cubic yards excavation, earth, at 30 cents	$60,000
30,000 cubic yards excavation, rock, at $1.50	45,000

500,000 cubic yards embankment, at 20 cents	$100,000
50,000 cubic yards puddling, at 10 cents extra	5,000
3,000 cubic yards protection, at $1.25	3,750
6 locks, at $15,000 each	90,000
8 culverts, at $1,500	12,000
10 crossing-bridges, at $450 each	4,500
Grubbing and clearing	300
1 aqueduct for Elk Lick	4,500
Repairing dam at mouth of Piney, &c	5,000
1 waste-weir	1,800
Land-damage, 100 acres, at $100	10,000
450 cubic yards abutment-masonry, at $8	3,600
Engineering and superintendence	15,000
Sums of items	360,000
Contingencies, 10 per cent	36,000
Cost of 5½ miles, averaging $72,000	396,000

Pleucher reservoir and feeder.

Dam with regulating and outlet pipes	$35,000
Meadow and Piney Run reservoirs and feeders	60,000
Sum of items, summit feeders	95,000

From Meyers' Mills to the vicinity of Connellsville the Board of Internal Improvements considered the work in three characteristic sections.

The first section west from Meyers' Mills of sixteen and one-eighth miles, with 216 feet of lockage and 27 locks, was estimated to cost $1,240,216, averaging $76,912.62 per mile. Deducting therefrom one and one-eighth miles from the Summit-level to the valley, where our line would join theirs, we get thus:

1st section, fifteen miles, 192 feet lockage	$1,163,304
2d section, nineteen and six-tenths miles, 420 feet lockage	1,459,317
3d section, twenty-seven and one-half miles, 432 feet lockage	1,515,437
Meyers' Mills to Connellsville, sixty-two miles	4,138,058
Increasing this estimate at the rate of 25 per cent. as found to apply to the section between Cumberland and Savage River	1,034,515
Sum representing estimate	5,172,573
Contingencies, 10 per cent	517,257
Cost of sixty-two miles, averaging $91,771.45	5,689,830

I have carried the estimate as far as Connellsville for the reason that I am informed that a company has been formed and incorporated by the State of Pennsylvania for the purpose of establishing slack-water navigation as far east on this line as Connellsville, or Ohio Pile Falls; and the section from Cumberland to Connellsville represents fairly the extent of canal needed to be provided to complete the water-line to Pittsburgh.

The recapitulation is as follows:

Cumberland to Savage River, 31 miles	$2,463,153
Mouth of Savage to Crabtree, 5½ miles	919,094
Crabtree to Summit, 11 miles	1,828,200
Summit-level and tunnel, 6½ miles	8,346,168
Summit to mouth of Piney, 5½ miles	530,640
Piney to Meyers' Mills, 6½ miles	396,000
Reservoirs and feeders, (Summit)	95,000
Meyers' Mills to Connellsville, 62 miles	5,689,830
Cumberland to Connellsville, 127½ miles, averaging $158,887 per mile	20,268,085

Comparing this estimate of cost with that of the Board of Internal Improvements for the same section of route between the same places, we have from their estimate:

Cumberland to Summit-level	$3,856,624
Summit-level	3,471,967

Summit to mouth of Castleman	$2,699,532
Castleman to Connellsville	1,515,437
Total, including reservoirs and feeders	11,543,560
If the tunnel and approaches had been taken of the same dimensions as for the Savage River route, they would have added	650,000
Making a total of	12,193,560
Adding 25 per cent., as before	3,048,390
We have	15,241,950
Contingencies, 10 per cent	1,524,195
Cost of ninety-eight miles, averaging $171,083.11	16,766,145

Showing an average of $12,739 more per mile than by our estimate.

The difference between the two estimates of $3,501,890, if reduced by the cost of the increased number of locks and greater length of tunnel on the Savage River route, will be but $2,003,000, reducing the average cost per mile to $147,207, indicating the more favorable character of the route in regard to cost of construction, as was stated in the description of the character of the route.

If, in further comparison of the Will's Creek and Savage River routes with reference to their costs now, we take into consideration that the Will's Creek route between Cumberland and Meyers' Mills is occupied by a railroad in operation holding almost the very ground on which the canal was located, in a valley of which a great portion is not wide enough for two such works, and wherein the canal would necessarily have to be located across the railroad several times under the most unfavorable conditions. and with a second railroad between Cumberland and Little Will's Creek, a distance of fifteen miles, the present recast of the former estimate would fall far short of the extraordinary expenses that are contingent upon the above conditions. It may be affirmed of the Savage River route that "*it would not cost more than the Will's Creek route.*"

The tunnel on the Deep Creek route was planned for a length of one and one-third miles, but the western deep-cut approach would be *five and one-quarter miles long.*

The quantities given in this estimate of cost are as correct as may be, without a more detailed survey and a definite location. The line of the proposed tunnel could not be surveyed to determine its precise length, nor the character of the approaches thereto, nor the location and depth of shafts, all which were determined from the preliminary survey. It is but a reasonable presumption that a careful study of the ground would indicate a somewhat shorter tunnel by correction of chaining and plat, and indicate favorable places for the approaches thereto, that would reduce the estimate of cost.

The strata that would be pierced by the tunnel are inclined at angles of 15° to 20°, are carboniferous, and contain a portion of the "*lower coal-measures,*" as described in Professor Lesley's report. The unfavorable condition of the pierced strata would necessitate the lining of the water-section of the tunnel to preserve the summit feed-water.

The tunnel is presumed to be operated by steam-tugs, for the reason that a sufficient number of them can be maintained and operated to accommodate the presumed business of the canal at a cost far less than the interest on the cost of increasing the size of the tunnel, so as to provide it with towing-paths; it is, however, wide enough to be operated in both directions at the same time, as it was thought that the delays in operating a long tunnel only wide enough for one boat would be very burdensome to business. Assuming a speed of three miles per hour through the tunnel, boats arriving shortly after a convoy had started through would be detained nearly four hours, and while waiting, if the season were a busy one, boats would rapidly accumulate until there would be more than could be taken through in one convoy, and a blockade that could not be remedied would be formed; in the same manner a narrow tunnel with a tow-path would cause a still more serious obstruction to business, as a convoy would consume at least three hours in passing through the tunnel, and thus there would be greater delays and unavoidable blockades. If steam should be brought to supersede horse-power on the canal, the tunnel would be favorably conditioned for accommodating the maximum traffic that could pass through other portions of the canal.

The tunnel could be operated with an endless chain, or wire rope, worked by stationary machinery, or by pneumatic tubes fixed on the sides of the tunnel in connection with fixed engines, so arranged as to tow single boats at from four to six miles per hour.

The present state of the enterprise does not warrant an investigation of these suggestions.

An examination has been begun to determine the conditions governing the introduction of inclined planes as substitutes for locks, their economic value as to cost, and economy of time, and water-supply, and their applicability for carrying canal-transit routes over high mountain-ranges.

COMMERCIAL IMPORTANCE.

Of the importance to be attached to the extension of the Chesapeake and Ohio Canal as one of the water-lines of transportation between the Atlantic seaboard and the great cereal-producing region of the great Mississippi Valley, nothing can be added to the volumes that have been devoted to that subject since Washington first interested himself in the scheme of improving the navigation of the Potomac River, with the ultimate purpose of bringing the products of the then West to the seaboard by this route.

The unparalleled development of the great West into a dense population of agriculturists and collaborators renders the necessity of extension of this route urgent, and the condition of monopolies controlling the transportation of the products of the West, establishing the condition of middlemen between the consumers and producers at a ruinous cost, brings about the clamorous demands for its early completion.

The products of the region referred to may be stated at 40,000,000 tons, of which 25,000,000 tons, at least, are destined for market. The capacities for carrying this eastward are as follows, based upon the work done by the routes named:

The Erie Canal carries in one year, tons	2,640,000
The Erie Railway, tons	895,000
The Pennsylvania Railroad, tons	880,000
The Baltimore and Ohio Railroad, tons	600,000
The New York Central Railroad	1,200,000
The other railway lines, say, tons	500,000
Total	6,715,000

Showing that only about one-fourth of the products seeking a market come direct to the East, and that more than one-third seeks the cheapness of the water-line.

The necessity and utility of additional cheap water-lines of transportation are apparent. Further illustration of the utility of this route as a through line of transportation is uncalled for, in view of the forthcoming report of the United States Senate committee on lines of transportation; but the local interests dependent on the *extension* of this route are worthy of special consideration.

The first consideration is the further development of the valley of the North Branch of the Potomac River above Cumberland and its several tributaries, in the progress of which the low rates of transportation by canal as compared with railroads are of the first importance.

The second important consideration is the establishment of canal transportation to the Cumberland coal-basin at Piedmont, twenty-eight miles beyond and west of Cumberland, by which convenience the cost of coal to the sea-coast market should be reduced by $1.65 per ton on present rates by railroads, and a dollar per ton on present combined rates on railroad and canal.

As a third consideration, there are extensive beds of the *lower coal-series*, described in the appended report of Professor Lesley, (Appendix B,) on the North Branch, from the mouth of Savage River to its headwaters, a length of some thirty miles, and extensive forests of the finest of timber, both on the North Branch and the Savage rivers, already in demand, and now taken to market under great disadvantages and at heavy cost.

But the most important feature, and the one promising the greatest benefit, one that will soon be demanded as a great necessity for the extension, is the fact that the Savage River route traverses the very valuable and extensive *Salisbury coal-basin*, which by calculation contains 90,000,000 tons of coal that can be brought to market out of a deposit estimated at 154,000,000 tons, lying above the beds of the Castleman River, at the place where this route enters the valley. The quantity available from the *lower coal-series*, lying below the bed of the river, is estimated at 90,000,000 tons out of a deposit of 120,000,000 tons. The upper beds can be worked by galleries and adits nearly horizontal, are readily drained, and are identical with the great Pittsburgh, Sewickly, and Cumberland beds, and of same general quality.

Late estimates of the quantity of coal remaining of the great vein of the Cumberland basin give, for 1869, 112,000,000 tons. This basin is being exhausted at the rate of 2,000,000 tons per annum, increasing at the rate of 5 per cent. each year, and at this rate will be exhausted in about twenty years; and the next available coal-field is the Salisbury basin, only some twenty miles more distant from the eastern markets, and yet within economic distance.

The Cumberland coal is now taxed by railroad freights $3.16 per ton per two hundred and twelve miles, quite nearly one and a half cents per ton per mile. This coal could be brought to the seaboard by canal for $1.06 per ton exclusive of tolls, which would be in full business, say 30 cents per ton, a total of $1.36 per ton, a saving to the consumer of $1.80 on present prices, or nearly 36 per cent.

The Salisbury beds are opened in several places, and a railroad is graded to connect with the Baltimore and Pittsburgh line. The Keystone Coal Company are mining and putting coal on the Baltimore and Pittsburgh Railroad by a narrow-gauge line at the rate of 150 tons per day; but the railroad monopoly obstructs the getting of the products of this coal-basin to market, and retards and delays the operations of mining; and consequently the Cumberland Coal Companies avoid competition; all which reacts on the prices at the eastern coal-markets, to the great disadvantage of all classes of consumers, domestic and productive.

For a faithful and full report on the Salisbury coal-basin with regard to quantity, quality, and geological identity, I am enabled to refer to the accompanying report of Prof. J. P. Lesley, for the use of which I am indebted to the courtesy of Mr. John Anspach, president of the Salisbury and Baltimore Railroad and Coal Company; I am also indebted to Mr. Frank T. Wilson, engineer for the company, for valuable information and professional courtesies.

That the lower coal-series can be extensively worked on the north branch above the mouth of Savage River is without question, as many places are opened to veins of 6 and 8 feet thickness, and even of greater thickness, near the head of that stream.

The importance of this extension is also apparent in regard to reaching the several coal-fields of the Youghiogheny, referred to in Professor Lesley's report.

Very respectfully,

THOMAS S. SEDGWICK.

Col. WM. E. MERRILL,
Major Engineers, U. S. A.

Appendix A.

REPORT OF THE BOARD OF INTERNAL IMPROVEMENT ON THE CHESAPEAKE AND OHIO CANAL, FEBRUARY 2, 1825.

This canal may be divided in three sections—eastern, middle, and western. The eastern section extends from the tide-water in the Potomac to the mouth of Savage River, in the northern branch of the Potomac. The middle section extends from the mouth of Savage River in the Potomac to that of Bear Creek in the Youghiogheny. The western section from the mouth of Bear Creek to the Ohio at Pittsburgh.

EASTERN SECTION.

[As this section has been built, all matters relating to it are omitted.]

MIDDLE SECTION.

This section, from the mouth of Savage River in the north branch of the Potomac, extends to the mouth of Bear Creek, in the Youghiogheny, on the west side of the Alleghanies. It includes the summit-level of the canal, and from the complicated topography of the ground, the height which must be overcome in a short space, and the difficulty of securing a sufficient supply of water in dry seasons at such an elevation, presents the greatest difficulties which occur in the whole project.

The Little Back Bone Ridge divides the waters, which, in that part of the Alleghanies, runs east and west; it runs parallel to the Great Back Bone, through which Savage River forces its way, and the canal must absolutely pass through this gap. Between those two ridges run Crabtree Creek, from southwest to northeast, and Savage River from northwest to southeast, the former falling into Savage River four and a half miles above its mouth in the Potomac. From the west side of the Little Back Bone falls Deep Creek and the Little Youghiogheny; the latter runs from east to west, and, after forcing its way successively through Hoop-pole Ridge and Roman Nose Ridge, joins the Great Youghiogheny. Deep Creek runs at first to the north, crossing Hoop-pole Ridge and Negro Mountain; then, intercepted by Marsh Mountain, it turns west and falls into the Youghiogheny. The gap through which it forces its way across the Hoop-pole Ridge is only sixty-six yards wide, and is called the Narrows.

The heads of the Little and Great Youghiogheny, to some miles above the point where they join in a single stream, run through marshy meadows known by the name of glades. The valleys of Deep Creek and its tributaries offer the same features as low down as Marsh Mountain, from whence their course continues in a deep and narrow ravine, with steep and rugged banks. The bottom of these glades, which has been sounded in several places, presents the following layers: first, rich loam; second, sand, colored by oxydated iron; third, vegetable detritics; fourth, alluvial clay; fifth, a horizontal bank of sandstone, 4 or 5 feet below the surface, on which the other layers all lie.

The Great Youghiogheny, after receiving the Little Youghiogheny and Deep Creek, receives Bear Creek. The east branch of this last stream rises on the west side of Negro Mountain, and runs from south to north till it forces its way through Keyser's Ridge; it then runs suddenly west, and, after forcing through Winding Ridge, falls into the Youghiogheny. Its west branch springs from the west side of Keyser's Ridge, and joins the other at the gap, where it forces its way through Winding Ridge.

Savage River runs on a bed of sandstone; its course is rapid, and broad flats extend along both its banks. Crabtree Creek is the chief tributary stream which joins it; it runs between the Great and Little Backbone, and is formed by the junction of Crabby's Arm and Wilson's Fork, which take their sources in that part of the Little Backbone which divides their ravines from the valley of the Little Yougbiogheny. Crabby's Arm runs in a narrow vale, but which is, however, wide enough to receive a canal; its bottom is a black, alluvial soil, and its banks present a gentle slope. Wilson's Fork is more rapid, but runs in a wide and well-wooded valley. These two streams join at Swan's Mill, from whence they impetuously descend on a bed from ten to twenty yards wide. They are interrupted in two or three places by perpendicular falls, 7 or 8 feet high, and frequently by smaller rapids, which fall from 4 to 5 feet. From the Great Backbone, Crabtree Creek receives several tributaries; they are torrents which fall into it with great impetuosity. On both sides of its valleys run flats eight or ten yards wide, which are intersected by rugged bluffs, from 100 to 200 feet high, which divide them into isolated portions, the bluffs on one side of the stream lying, in general, opposite to the flats on the other, and the two banks presenting an alternate succession of the same features.

Such are the main streams which, in this section, descend from the two sides of the Alleghanies.

To conduct the canal across this summit ground we must, 1st, select the best passage for it through the Little Backbone, by leading it either from the valley of Savage River to that of Deep Creek, and from that of Crabtree Creek to the same, or from the valley of Crabtree Creek to that of the Little Youghiogheny; 2d, ascertain which of these passages presents the shortest route from the mouth of Savage River to that of Bear Creek; 3d, ascertain, as the most essential element of the whole project, whether a supply of water sufficient for all the purposes of the canal can be procured at this elevation.

We shall point out the several passages which lead through the Little Backbone, beginning by those which lead from the valley of Savage River to that of Deep Creek. But, in the first place, it is necessary to state that a base-mark has been fixed on the bridge of Deep Creek, 3 feet above its bottom; to this have been referred all the levels taken on this section of the canal.

Monroe Run, a tributary of Savage River, and Meadow Mountain Run, a tributary of Deep Creek, offer the only ravines through which Deep Creek and Savage River can be connected. For this purpose it will be necessary to run a tunnel through the Little Backbone. Supposing its bed on a level with the base-mark, and a deep cut of 35 feet at each extremity of it, this tunnel would extend five miles 833⅓ yards in length. The greatest elevation of the ridge above the bed of the tunnel would be 213 feet. From its eastern extremity to the mouth of Monroe Run, in Savage River, the descent is 983 feet, on a length of five miles 816⅔ yards. From the mouth of Monroe Run to that of Crabtree Creek, in Savage River, the descent is 109 feet on a length of 2 miles 216⅔ yards. From the mouth of Crabtree Creek to that of Savage River itself, in the Potomac, the descent is 340 feet, on a length of five and one-half miles. The level of the mouth of Savage River lies, of course, 1,432 feet below the base-mark, and at a distance of twenty-one miles 327 yards from it, ascending the ravines of Savage River and Monroe Run, and descending those of Meadow Mountain Run and Deep Creek.

Meadow Mountain Run flows through glades, but Monroe Run falls down a ravine whose upper portion is very steep and narrow; it widens, however, as it descends, and presents a succession of bluffs and flats, which extend to twenty-five yards in breadth. The bluffs hang perpendicularly over the stream. At the mouth of Monroe Run, Savage River is only thirty-three yards wide, and a dam might easily be thrown across to form a reservoir.

This passage is the only one which leads from the valley of Savage River to that of Deep Creek.

We shall now examine those which connect the valley of Crabtree Creek and Deep Creek. The first lies between the middle fork of Crabtree Creek and the Meadow Mountain Run, and would require a tunnel running under the Little Backbone and Hoop-pole Ridge. Supposing its bed on a level with the base-mark, and an open cut to the depth of 35 feet through the height, the tunnel would extend three miles 1,333⅓ yards in length. From its eastern extremity to Crabtree Creek, in following the windings of the middle fork, the descent is 1,012 feet on a distance of six miles 1,333⅓ yards; and from the mouth of the middle fork to the mouth of Savage River, in the Potomac, the descent is 420 feet on a distance of six miles 685 yards. The height of the ridge above the bed of the tunnel would be 210 feet, and the ravine of middle fork differs little from that of Monroe Run. Its general breadth is about 27 yards, and its banks are rugged. The whole distance from the base-mark to the mouth of Savage River would be, by this passage, nineteen miles 915 yards.

Three passages run through the Little Backbone from three branches of North Glade Run, a tributary stream of Deep Creek, to the valley of Crabtree Creek.

The first opens on the western branch of the middle fork, and would require a tunnel through the Hoop-pole Ridge. Supposing its bed on a level with the base-mark, and an open cut to the depth of 35 feet through the height, the tunnel would extend three miles 125⅛ yards in length, and the greatest height of the ridge above its bed would be 144 feet.

From the second branch of North Glade Run a passage might be opened to the eastern branch of the middle fork by a tunnel of the same nature and on the same level as the former. It would extend three miles and 83 yards in length, and the greatest height of the ridge above its bed would be 184 feet. But from its eastern extremity there would be a descent of 280 feet on a distance of one mile 366 yards.

From the third branch a passage might be opened to Rock Camp Run by a tunnel four miles in length. The greatest height of the ridge above its bed would be 222 feet; but from its eastern extremity to Crabtree Creek the descent would be 728 feet on a distance of two miles 166⅞ yards, and through a very narrow, rugged, and precipitous ravine. The north fork of Deep Creek rises near the summit of the Little Backbone at Whitsall's Springs, 105 feet above the base-mark. The spring of Savage Lick Run, a tributary stream of Crabtree Creek, rises opposite to it. A tunnel which would join them, with its bed on a level with its base-mark, and an open cut through the height at each of its extremities to the depth of 35 feet, would extend two miles 1,083 yards in length. From its eastern extremity to Crabtree Creek the descent would be 452 feet on a distance of two miles and 100 yards, and the greatest height of the ridge above its bed would be 148 feet.

Three more passages have been surveyed between the tributaries of the north fork and those of Crabtree Creek.

The first unites Hinch's Arm to Glade Road Run by a tunnel one mile 1,166 yards in length on a level with the base-mark. The distance from its eastern extremity to Crabtree Creek is 1,500 yards, and the greatest height of the ridge above its bed 205 feet.

The two others unite Dry Arm and Dewickman's Arm wih small ravines of Crabby's Arm, a tributary stream of Crabtree Creek, which rise opposite to them. The tunnel which would be required at Dry Arm would extend one mile 916 yards in length, and the greatest height of the ridge above its bed would be 271 feet. The tunnel of Dewickman's Arm would extend one mile 683⅛ yards in length and the greatest height of the ridge above its bed would be 227 feet. These two tunnels, on a level with the base-mark, are the shortest of those that we have enumerated on any of the designed routes of the canal.

Two passages have been surveyed and leveled to open a communication between Crabtree Creek and the Little Youghiogheny, the one from Crabby's Arm and the other from Wilson's Fork to the latter stream. They would each require a tunnel. Supposing its bed on a level with the base-mark, the tunnel from Crabby's Arm would extend three miles 1,568 yards, and the tunnel from Wilson's Fork four miles 300 yards in length, with an open cut at each of their extremities to the depth of 35 feet. The greatest height of the ridge above the bed of the tunnel from Crabby's Arm would be 444 feet, and above that of Wilson's Fork 253 feet. The distance from their eastern extremities to Swan's Mill would be two miles, with a fall of 114 feet from Swan's Mill to the mouth of Crabtree Creek the descent would be 940 feet on a distance of seven miles 966 yards; from the mouth of Crabtree Creek to that of Savage River, on the Potomac, the distance five miles 880 yards, and the descent 378 feet. Thus from the eastern extremity of the tunnel to the mouth of Savage River the total descent is 1,432 feet on a distance of fifteen miles 86 yards, and of these two tunnels the one by Crabby's Arm is the shortest.

Other passages have also been examined to open communications between Deep Creek and the waters of the Little Youghiogheny. The bed of the tunnels required for this purpose was fixed 17 feet above the level of the baso-mark. One of these tunnels join Westlick Run to one of the branches of the South Fork of Deep Creek. Its length was two miles 583⅛ yards, and it required a deep cut on the side of Westlick Run of the length of one mile 600 yards, and another on the side of South Fork of the length of two miles 50 yards. Another tunnel might join the Little Youghiogheny itself to South Fork. It would extend one mile 1,300 yards in length, and require an open cut of one mile 1,566⅞ yards in length toward the Little Youghiogheny, and two miles 300 yards toward the South Fork. The height of the ridge above the first tunnel would be 143 feet, and above the second, 183 feet.

Such are the chief passages through which a communication might be opened between the waters which descend from the eastern and western sides of the Little Backbone.

In recapitulating the several routes by which the canal may be directed through them, we will observe that they all extend from the mouth of Savage River, either by the valley of that stream or Crabtree Creek, to the base-mark on the bridge of Deep Creek, and that the descent or fall of the canal by all these routes is 1,432 feet,

1st. The first ascends by Savage River, Monroe Run, Meadow Mountain Run, and Deep Creek. Its total length, from the mouth of Savage River to the base-mark, is twenty-one miles 325 yards. The length of the tunnel which it requires through the ridge is five miles 833⅓ yards, and the height of the ridge above its bed, 213 feet.

2d. The second ascends by Savage River, Crabtree Creek, Middle Fork, Meadow Mountain Run, and Deep Creek. Its total length is nineteen miles 915 yards. The length of the tunnel which it requires through the ridge is three miles 1,333⅓ yards, and the height of the ridge above its bed is 210 feet.

3d. The third ascends by Savage River, Crabtree Creek, Middle Fork, the western branch of the same fork, North Glade Run, and Deep Creek. Its total length is twenty miles 1,128 yards; the length of the tunnel which it requires through the ridge, three miles 125 yards, and the height of the ridge above its bed, 144 feet.

4th. The fourth ascends by Savage River, Crabtree Creek, Middle Fork, the eastern branch of the same, North Glade Run, and Deep Creek. Its total length is twenty miles 1,306 yards; the length of the tunnel which it requires through the ridge, three miles 83 yards; the height of the ridge above its bed, 184 feet.

5th. The fifth ascends by Savage River, Crabtree Creek, Rocky Camp Run, North Glade Run, and Deep Creek. Its total length is nineteen miles 630 yards; the length of the tunnel which it requires through the ridge, four miles, and the height of the ridge above its bed, 222 feet.

6th. The sixth ascends by Savage River, Crabtree Creek, Savage Lick Run, North Fork, and Deep Creek. Its total length is twenty-one miles 435 yards; the length of the tunnel which it requires through the ridge, two miles 1,083 yards, and the height of the ridge above its bed, 148 feet.

7th. The seventh ascends by Savage River, Crabtree Creek, Hinch's Arm, Glade Road Run, North Fork, and Deep Creek. Its total length is twenty-one miles 1,156 yards; the length of the tunnel which it requires through the ridge, one mile 1,166 yards, and the height of the ridge above its bed, 205 feet.

8th. The eighth ascends by Savage River, Crabtree Creek, a ravine of Crabby's Arm, Dry Arm, North Fork, and Deep Creek. Its total length is twenty-one miles 1,368 yards; the length of the tunnel which it requires through the ridge, one mile 916 yards; and the height of the ridge above its bed, 271 feet.

9th. The ninth ascends by Savage River, Crabtree Creek, a ravine of Crabby's Arm, Dewickman's Arm, North Fork, and Deep Creek. Its total length is twenty-one miles 718 yards; the length of the tunnel which it requires through the ridge, one mile 683⅓ yards; and the height of the ridge above its bed, 227 feet.

From the base-mark the localities of the ground leave us a choice between three routes to the mouth of Bear Creek.

The first runs by Deep Creek, Buffalo Marsh Run, Rocklick Run, a tributary stream to the western branch of Bear Creek, that western branch to its mouth in Bear Creek, and Bear Creek itself to the Youghiogheny. This route crosses, by a tunnel, the ridge which divides the heads of the western and eastern branches of Bear Creek. This tunnel beginning at McHenry's, and with an open cut of the depth of 35 feet at its southern extremity, near McHenry's, and at its northern extremity, would extend about two miles in length, and the greatest height of the ridge above its bed, supposed on a level with the base-mark, would be about 170 feet. The whole ground along this route, except where it passes through the gap of Winding Ridge, is of a soft and good quality; and its whole length, from the base-mark to the mouth of Bear Creek, would be only twelve miles.

A second route might turn round the west of Marsh Mountain, and wind about Panther's Point. It would then turn successively round the heads of the ravines of Hoy's Run, Steep Run, Sang Run, Gap Run, and descend along Friend Run, a tributary of the western branch of Bear Creek. This route is very circuitous, and in winding round Panther's Point runs through a rocky and difficult ground. It could only be shortened by running an aqueduct 250 feet high, and above a quarter of a mile long, through the western branch of Hoy's Run, or a tunnel half a mile in length from that western branch to the head of Steep Run. The height of the ridge above the bottom of that tunnel would be about 250 feet. A level was also run over a bend of ground at Hoy's Pine Bottom to endeavor to shorten it and avoid the winding round of Panther's Point, but to run the canal over this line would require a deep cut of 1,431 yards in length, and of the depth of 99.06 feet, at the highest point of the ridge. The total length of this route would be twenty-four miles.

The third route, descending the valley of Deep Creek from the base-mark, might follow the eastern shore of the Youghiogheny to the mouth of Bear Creek, crossing successively on aqueducts Hoy's Run, Steep Run, Sang Run, Gap Run, Bear Creek, and the smaller tributary streams of that river. The ground along this route is rocky and difficult for one mile and three-quarters from Deep Creek to Hoy's Run; then light and easy for four miles to Gap Run; then rocky for the space of six miles, following the western bank of Winding Ridge; then for two and a quarter miles light and easy to the mouth of Bear Creek. The total length of this route would be twenty miles.

We have not mentioned a fourth route, which, from the base-mark, running by a tunnel through Negro Mountain, might unite Deep Creek with the eastern branch of Bear Creek, because it would require a tunnel of eight miles in length, and that the height of the ridge above its bed would be from 400 to 500 feet in the most elevated portion. The length of this route would also pass twenty miles.

Such are all the routes which lead from the valleys of Savage River and Crabtree Creek, in passing by that of Deep Creek to the mouth of Bear Creek, in the Youghiogheny. We must now examine those which, departing from the head of Crabtree Creek, reach the same point in passing by the valleys of the Little and Great Youghiogheny.

For this purpose the canal should follow the valley of Savage River from the mouth of that stream, and ascend along Crabtree Creek till it reaches two miles above Swan's Mill, where opens the eastern extremity of the tunnel of Crabby's Arm, mentioned on page 10 as the shortest of those by which Savage River can be connected with the Youghiogheny. Passing through that tunnel it would descend the valleys of the Little and Great Youghiogheny, winding along their eastern sides. When it reaches the mouth of Deep Creek, it may follow one of these three directions:

1st. Ascend Deep Creek and Buffalo Marsh Run, following the first of the three routes which we have just indicated for passing from the base-mark to the mouth of Bear Creek. This route, as we have seen, presents a tunnel two miles in length. The total distance over which it runs is as follows:

	Miles.	Yards.
From the mouth of Savage River to the east extremity of the tunnel of Crabby's Arm	15	86
From thence to the mouth of Deep Creek	22	426
From thence to the mouth of Buffalo Marsh Run	6	...
From thence to the mouth of Bear Creek	11	440
Total distance from the mouth of Savage River to that of Bear Creek	54	952

This route would present two tunnels, one three miles 1,538 yards in length at Crabby's Arm, and the other two miles in length between Buffalo Marsh Run and Rocklick Run; total, nearly six miles of tunneling.

2d. The canal might cross Deep Creek and follow the second route indicated for passing from the base-mark to Bear Creek, by winding round Panther's Point, and the heads of the ravines of Hoy's Run, Steep Run, Sang Run, Gap Run, and Friend Run to the western branch of Bear Creek. Its total length would be:

	Miles.	Yards.
From the mouth of Savage River to that of Deep Creek, as above	37	512
From thence to Bear Creek	17	660
Total length	54	1,172

This route presents only one tunnel, of the length of three miles 1,538 yards, or nearly four miles, at Crabby's Arm. It may also be shortened, as mentioned above. by an aqueduct one-fourth of a mile in length and 250 feet high, or a tunnel one-half mile in length, with 250 feet of height of ridge above its bed.

3d. The canal might fall on this third route indicated above, after crossing Deep Creek, by keeping along the eastern side of the valley of the Youghiogheny, and crossing its tributaries on aqueducts. Its total length would be as follows:

	Miles.	Yards.
From the mouth of Savage River to that of Deep Creek, as above	37	512
From thence to Bear Creek	13	660
Total length	50	1,172

This route would require, like the preceding one, one tunnel, of three miles 1,538 yards, or nearly four miles in length.

From the comparison of these three routes it is evident that the second is preferable to the first. Their length is nearly the same, but the first requires six miles of tunneling and two tunnels, while the second requires only one tunnel, of something less than four miles in length. The third is shorter again, by four miles, than the second, and passes by the same tunnel. Aqueducts must be constructed on this route to cross Hoy's Run, Steep Run, Sang Run, Gap Run, and Bear Creek, but by the successive dropping of its levels they will require but a small elevation, and the waters of these runs and of the Great Youghiogheny may be raised and used to feed the canal, an advantage which the other routes do not offer. It should also be observed that these runs are not above 200 or 300 feet wide at their mouths in the Youghiogheny. The third route is therefore preferable to the two others, on the hypothesis of uniting the mouths of Savage River and Bear Creek through the valleys of the Little and Great Youghiogheny.

We will now compare this route, which we will call the Youghiogheny route, with those which lead from Crabtree Creek to Deep Creek.

Nine routes, which all unite at the base-mark, have, as we have stated before, been examined for this purpose. Their length varies only from nineteen to twenty-two miles, but their tunnels present a much greater difference. The longest extends five miles 833⅛ yards, or about five and a half miles; and the shortest, one mile 683⅛ yards, or about one and one-third miles in length. The last should certainly be preferred. Its whole length is twenty-one miles 718 yards; and the greatest height of the ridge above its tunnel is 227 feet. We shall call it Dewickman's Arm route.

We have also observed that there are three routes from the base-mark to the mouth of Bear Creek. The first runs twelve miles, by Buffalo Marsh Run, and Rock Lick Run. It is the shortest, but requires two miles of tunneling. Were it not for this obstacle it offers a favorable ground for digging the canal. The second, winding round Panther's Point and the heads of Hoy's Run, Steep Run, Sang Run, Gap Run, &c., is twenty-four miles long, and is objectionable, not only for its length, but from the difficulties which it presents in turning Panther's Point. The third, by the valleys of Deep Creek and of the eastern bank of the Youghiogheny, is twenty miles long. It is shorter by four miles than the second, and requires no tunneling. In this respect it is superior to the first; for two miles of tunnel costs more than eight miles of canal, which is the difference of their length. The passage of an active trade will also meet with more delay on a tunnel of two miles, unless its dimensions are very large, than on four or six miles of canal. This route possessing, besides, over the two others, the advantage of feeding the canal below the mouth of Deep Creek, by raising the waters of the Great Youghiogheny and its tributaries, is preferable to them in all respects.

If we add the twenty miles of this route to the twenty-one miles 718 yards of Dewickman's Arm route, we shall have for the whole length of the canal, passing along Cabtree Creek, Deep Creek, and the valley of the Youghiogheny, forty-one miles 718 yards, with one tunnel one and a third miles in length, and the height of the ridge above it 227 feet. We shall call this route Deep Creek route, in opposition to the Youghiogheny route.

To decide between these two routes, which alone can enter in competition, we must compare their length, and the time, expense, difficulties, and trouble of their construction, viewed in a general manner.

The length of the Deep Creek route is forty-one miles 718 yards; that of the Youghiogheny route fifty miles 1,172 yards. The former is, therefore, shorter by nine miles than the other.

The tunnel from Dewickman's Arm on the Deep Creek route is one mile 683⅛ yards in length, and the height of the ridge above its bed is 227 feet. The tunnel between Crabby's Arm and the Little Youghiogheny, on the Youghiogheny route, is three miles 1,538 yards in length, and the height of the ridge above its bed is 464 feet. The former requires two miles 855⅜ yards less of tunneling, and the height of the ridge above the bed of its tunnel is 237 feet less. With respect to the expense of tunneling, the route by Deep Creek is, therefore, preferable to the other.

As to the deep cuts at each extremity of these tunnels, the deep cut at the western extremity of the tunnel, toward the Little Youghiogheny, is two miles 930 yards in length. The deep cut at its eastern extremity, toward Crabby's Arm, is 900 yards. The whole deep cutting on the Youghiogheny route is thus three miles 70 yards.

The deep cut at the western extremity of the other tunnel, toward Deep Creek, extends five miles 1,096 yards. The deep cut at its eastern extremity, toward Dewickman's Arm, 572 yards. Total, five miles 1,668 yards.

The Youghiogheny route will therefore require two miles 1,598 yards less of deep cutting than the other at the extremities of its tunnels. But this advantage is not to be weighed with the expense of two miles 855 yards more of tunneling.

In comparing the nature of the soil on each of these routes and the obstacles which it may present, it must be remembered that their eastern portion, from Savage River to Crabby's Arm, and their western portion, from the mouth of Deep Creek to that of Bear Creek, are the same. In the intermediate space the ground is equally favorable and easy to work on both routes.

On the whole comparison of their respective lengths, of the time necessary to pass through the one or the other of the obstacles which they meet, and the expense and probable trouble of their construction, we believe the Deep Creek route preferable to the route by the Youghiogheny.

Our next task must be to compare the supplies of water which the canal may receive on either of these routes, and this will lead us to a detailed investigation of the resources which are offered by the water-courses of the country to feed the middle section and summit-level of the proposed canal.

Savage River and its tributary, Crabtree Creek, may feed the eastern branch of the middle section, and the great Youghiogheny its western branch. The summit-level must draw its resources from Deep Creek and the heads of the Little and Great Youghiogheny.

These streams were all gauged in 1824 at their lowest stage. We will give, in a general manner, the result of these operations, the minimum, in cubic feet of water, that flows through each stream in a second.

EASTERN BRANCH OF THE MIDDLE SECTION.

	Cubic ft.
Savage River gave on the 28th September below the mouth of Crabtree Creek, in a second	17.73
Savage River gave on the 28th September at its mouth, (it had, however, rained this day)	46.09
Savage River gave on the 2d September below Monroe Run	28.62
Monroe Run gave on the 28th September at its mouth	0.88
Monroe Run gave on the 16th September at its mouth	2.25
Crabtree Creek gave on the 14th September at Swan's mill	0.97
Middle Fork gave on the 15th September at its mouth in Crabtree Creek	0.84
Rock Camp Run gave on the 2d September at its mouth in Crabtree Creek	0.12
Savage Lick River gave on the 14th September at its mouth in Crabtree Creek	0.33
Crabby's Arm gave on the 17th August at its mouth in Crabtree Creek	0.24
Wilson's Fork gave on the 17th August at its mouth in Crabtree Creek	0.35

If we consider that the water consumed in the lockage of this branch is supplied from the summit-level, these streams, turned into reservoirs by dams thrown across the tributaries of Crabtree Creek and Savage River, above the mouth of that creek, will serve to supply its losses from filtrations and evaporation. Between the mouth of Crabtree Creek and the Potomac, on a distance of five and one-half miles, Savage River, which gives 17.73 cubic feet in a second at its lowest stage, will serve for this purpose. In the remaining nine and one-half miles from the tunnel to the mouth of Crabtree Creek the Middle Fork gives 0.84 cubic foot; Rock Camp Run, 0.12 cubic foot; Savage Lick Run, 0.33 cubic foot; and Crabtree Creek itself, 0. 97 cubic foot, at Swan's mill, at their lowest stages; total, 2.26 cubic feet. Reservoirs may besides be formed in the Middle Fork, Savage Lick Run, and Rock Camp Run. Filtrations may also be prevented, in a great degree, by a careful construction of the bed of the canal; and from observations taken in the summer of 1824 the loss from evaporation did not exceed the quantity received by summer rains. It may also be observed that any deficit will prove to be amply supplied by the waters of the summit-level.

From the mouth of Savage River the canal may be supplied from the North Branch of the Potomac, which, on the 18th September, gave 106 cubic feet in a second; and a great reservoir may be formed in it above the mouth of Savage River. From this point, therefore, it needs no longer the waters of Savage River nor of its tributaries. And if we except the waters required for its lockage, which will be supplied from the summit-level, this branch of the middle section may be fed in a great degree by the streams which fall into it.

WESTERN BRANCH OF THE MIDDLE SECTION.

This portion of the canal begins in Deep Creek, five miles below the base-mark, and ends at the mouth of Bear Creek. Its length is fourteen and three-fourths of a mile, and, like the former branch, it will receive from the summit-level the waters required for its lockage.

Hoy's Run, Steep Run, Sang Run, and Gap Run may be employed to feed it and repair its losses; but these streams have not been gauged. They may, nevertheless, offer some resources for reservoirs. Bear Creek may also form a great reservoir, by damming its valley and feeding the western section of the canal, but cannot feed the western branch of the middle section, from the difference of their levels.

Deep Creek is the only stream of any importance whose waters may supply the losses of this branch from filtrations and evaporation. We should, therefore, examine accurately the means which it offers for this purpose. Its usual depth under the bridge is 3 feet; but in its freshets it rises to 12 feet. High freshets generally occur in this stream twice or thrice a year, and last from three to four days; when the rains last so long, it gives, during that time, from 400 to 500 cubic feet a second. During the most unfavorable season it still has freshets, less considerable, but which, nevertheless, give it a mean discharge about 100 cubic feet in a second each time; these occur from six to eight times a year. In the dryest months it gives, under the bridge, from 10 to 5½ cubic feet a second; on the 27th August, 1824, it gave 5.12 cubic feet, which was the lowest quantity we ever found.

Supposing a dam erected across Deep Creek at the head of its rapids, and five miles below the base-mark, its basis would be 19¼ feet below that mark; its length would be 136⅜ yards, and to raise its waters 4 feet above the base-mark its height should be 23¼ feet. This dam would raise the waters of Deep Creek so as to overflow an area of 948,924 square yards, from accurate surveys. The prism of this reservoir, comprised between its surface and a horizontal plane, run 3 feet below the base-mark, would be 7 feet high, and contain in capacity 2,214,156 cubic yards. In less than three months of the rainy season, if we allow only 9 cubic feet, or one-third of a cubic yard a second to the average supply of Deep Creek, this reservoir would be filled. It would be filled in less than five months in summer if the stream yielded at the rate of 5 cubic feet. Thus, every year, and for nine months of navigation, from the middle of March to the middle of December, we may depend on a supply equal to twice the capacity of this basin, or 4,428,312 cubic yards. This is equivalent to 492,034 cubic yards a month, and supposes only a mean supply of 5⅛ cubic feet a second. This is the minimum of what Deep Creek can supply to repair the losses of the western branch of the middle section from filtrations and evaporation. To ascertain its sufficiency, we must examine next what those losses may amount to.

The length of this section is fourteen and three-quarter miles. Supposing it 5 feet deep, 28 feet broad at the bottom, and 44 feet at the surface of the water, the prism of its capacity will have a base of 20 cubic yards, on a length of fourteen and three-quarter miles, equal to a cube of 519,200 cubic yards. This will be filled in the first days of March without deranging the economy of water which we have just analyzed. We have already observed that Deep Creek may supply every month a cube nearly corresponding to this, or 492,034 cubic yards, at the minimum rate, and lowest stage of its flow; we must now examine whether this supply will suffice every month to the filtrations and evaporation of fourteen and three-quarter miles of canal.

Without entering into minute calculations which properly belong to the report accompanying the final project of the canal, we will state generally the most positive results which experience has given as to the joint amount of filtrations and evaporation. Having ascertained that no experiments of this nature have been tried on the Erie Canal, where the supply of water was found evidently more than sufficient, we were obliged to consult the results of those canals constructed in Europe, under a climate which, in the summer, comes nearest to our own. We have selected for this purpose the canal of Narbonne, in the south of France. Narbonne and Baltimore, compared as to climate and rain, are as follows:

Narbonne, latitude north 43° 11′, (from observations made during twenty years.) Mean greatest heat, 95°; mean temperature, 60°; mean greatest cold, 24°; mean quantity of rain, 29.30 inches.

Baltimore, latitude north 39° 17′, (from observations made 1817–1822, by Mr. Lewis Brantz, of Maryland.) Mean greatest heat, 94°.56; mean temperature, 52°.23; mean greatest cold, 0°.12; mean quantity of rain, 38.60 inches.

Of all such works, the canal of Narbonne has given most trouble to its engineers, from its excessive filtrations and loss of water in the gravelly soil through which it is run. It is a branch from the canal of Languedoc to the city of Narbonne, three miles in length. As soon as it was opened, in 1788, it lost the value or contents of its prism in a few days and overflowed the surrounding country; in 1789 it still lost the value of its prism in six days; and in 1800 it lost it in eighteen days, or the value of its prism and two-thirds every month—sixteen and two-thirds times its contents in ten months' navigation. This evaluation is the result of careful and accurate observations; and, considering the climate and soil through which this canal runs, it may fairly be taken as a specimen of the maximum loss which a canal can suffer through filtrations and evaporation.

The ground through which runs the western branch of our middle section is of a quality far superior to the country through which runs the Narbonne Canal. It is, for six and one-fourth miles, of an excellent quality; the remaining eight and one-half miles run through a rugged and rocky soil, but clay is everywhere at hand to puddle the bed of the canal, if necessary. Supposing, therefore, that its losses from filtrations and evaporation equaled in one month the cube of its prism, or 519,200 cubic yards, this would certainly be their maximum, while the evaluation of 492,034 cubic yards of water, which we have given as the supply from the reservoir of Deep Creek in one month, is its minimum. For it must be remembered that we valued this supply from the lowest result, obtained at the lowest stage of Deep Creek, when it gave only five and one-eighth cubic feet in a second.

We have allowed no loss for the evaporation from the surface of the reservoir, as it will be compensated by the frequent rains which fall on the summit of the Alleghany. From observations made in July, August, September, and October, 1824, in the valley of Deep Creek, we have ascertained that there fell, from 19th to 30th July, four days of rain, 4.36 inches, 55° mean temperature; from 1st to 31st August, eight days of rain, 2.31

inches, 63° mean temperature; from 1st to 30th September, twelve days of rain, 3.15 inches, 51° mean temperature; from 1st to 31st October, nine days of rain, 3.19 inches, 44° mean temperature; from 19th July to 31st October, thirty-three days of rain, 13.01 inches. During one hundred and four days, of which thirty-three were rainy, there fell 13.01 inches of rain. The evaporation was 0.10 inch a day, and during the one hundred and four days, 10.40 inches; of course the rain more than supplied the loss of evaporation.

The temperatures marked above are the mean temperatures of the rainy days. The highest temperatures in that valley, during these months, were at midday; in July, 76°; in August, 74°; in September, 70°; in October, 72°. The lowest were at 6 in the morning; in July, 53°; in August, 44°; in September, 32°: in October, 25°. From these observations it is evident that less evaporation is to be apprehended in the valley of Deep Creek than in regions nearer to the level of the ocean; besides, by raising the dam which forms its reservoir, we might add to it a quantity of water sufficient to supply all the loss of its evaporation and filtration. We will conclude these remarks on the reservoir of Deep Creek by observing that its surface lies below the mouths of its tributaries, and that they might, therefore, at small expense, be turned into reservoirs to preserve the waters of the valley, when (the great reservoir of Deep Creek being full) they would otherwise escape over the dam. For this purpose, the dams of these small streams should have sluice-gates, to distribute their supplies whenever required.

SUMMIT-LEVEL OF THE MIDDLE SECTION.

From these observations it is evident that the eastern and western branches of the middle section possess sufficient supplies to repair their losses from filtrations and evaporation. The first is fifteen, and the second fourteen and three-fourths miles in length; and both, twenty-nine and three-fourths miles. If we subtract this length from that of the whole Deep Creek route, forty-one miles 718 yards, there will remain eleven miles 1,158 yards, or about eleven and three-fourths miles. If we subtract it from the length of the Youghiogheny route, (fifty miles 1,172 yards,) there will remain twenty miles 1,580 yards, or about twenty-one miles. These portions, on either of these routes, may be designated as their summit-levels. On the Youghiogheny route this portion might, perhaps, be dropped below the reservoirs of the Youghiogheny; but its length and expanse of water, which is our present object, would remain the same on either level. We should now examine, first, what means exist to feed these summit-levels; second, what each of these requires to supply all its wants and losses; third, what are the respective advantages of the one and the other, and which is the most advantageous with respect to that question.

The Great and Little Youghiogheny and their upper tributaries are the only streams of any importance which can feed either of these summit-levels. Their levels with respect to the base-mark, and at different points, are as follows:

	Feet.
Level of the Great Youghiogheny, at the mouth of Deep Creek below the base-mark	250.00
Level of the Great Youghiogheny, at the head of Swallow Falls, below the base-mark	140.81
Level of the Great Youghiogheny, one mile above the mouth of Indian Run, below the base-mark	70.50
Level of the Great Youghiogheny, two miles above the mouth of Indian Run, below the base-mark	64.00
Level of the Great Youghiogheny, at the mouth of the Little Youghiogheny, below the base-mark	53.00
Level of the Great Youghiogheny, at the mouth of Snow Creek, two miles above the bridge, below the base-mark	36.69
Level of the Great Youghiogheny, at Charles Glade's Run, below the base-mark	28.72
Level of the Great Youghiogheny, at the mouth of Cherry-tree Creek, below the base-mark	26.18
Level of the Little Youghiogheny, where it is crossed by the State road, below the base-mark	44.00

These levels being all below the base-mark, proved that whichever summit-level we adopt we must elevate the waters of the two Youghioghenies by throwing great dams across them. The height of these dams would be lower and a less quantity of lockage required if we dropped the summit-level of the Youghiogheny route; but the length of the tunnel from Crabby's Arm, and deep cutting at each of its extremities, would then be proportionably augmented. For the sake of comparison, we have, therefore, supposed those two routes on a level. A passage was sought to open a communication between Deep Creek and the Great Youghiogheny through the opposite valleys of

Indian Run and Cranberry Run. But as the sources of these runs rise 226 feet above the base-mark, and the Youghiogheny at the Indian Run lies 70.50 feet below it, a dam across the Youghiogheny, and tunnel through the Roman Nose Ridge, would both be indispensably required to accomplish this object.

An attempt was also made to lead Muddy Creek, which from the west falls in the Youghiogheny, to the summit-level of these routes. But to lead it to the summit-level of the Deep Creek route it would be necessary to conduct it by a long aqueduct upward of 140 feet high, and to lead it to that of the Youghiogheny, to run a feeder upward of thirty miles before it reached the mouth of Indian Run, and which would absorb by filtrations and evaporation, during its course, most of the water which it would receive. Aqueducts through the ravines which it should wind around would shorten it, but a great number of them would be required, and their construction would be very costly.

To ascertain the relative levels of Pine Swamp (where rise the springs of Muddy Creek of Youghiogheny, and Muddy Creek of Cheat River) and Deep Creek, a level was run to the summit of the ridge which divides the waters of the Youghiogheny and Cheat Rivers; this ridge, parallel to the Roman Nose Ridge, is called Snaggy Mountain. From this level it appeared that the point from which rise the highest springs of the two Muddy Creeks is 75 feet above Pine Swamp, and 226.77 feet above the base-mark. This result, which proved the impossibility of running the canal in this direction from the mouth of Deep Creek, proved also that a reservoir of three or four miles area might be formed in the Pine Swamp, and that being raised at least 150 feet above the base-mark, a feeder might be led from it, following the eastern ridge of Snaggy Mountain, and joining Snowy Creek, after winding around the heads of the tributaries of the Youghiogheny, from Snowy Creek to Muddy Creek. This feeder would be from eight to twelve miles long, and to form the reservoir a dam might be thrown through Muddy Creek, of the Youghiogheny, at the gap where it breaks through Snaggy Mountain. This reservoir would afford an important supply, if those of the Little and Great Youghiogheny should prove insufficient to feed the summit-levels. We shall now enumerate and measure the capacity of these several reservoirs, and give all the necessary details of them.

Reservoir No. 1 might be formed in the main branch of the Great Youghiogheny by throwing a dam across it, above the mouth of Cherrytree Creek. It should be 40 feet high to raise the water 6 feet above the summit-level and allow to the feeder a descent of 6 inches per mile; height of its dam, 40 feet, and length of its feeder, to the dam in Deep Creek, sixteen miles. Area of the reservoir exposed to evaporation, 2,894,333 square yards; its prism, or capacity of water above the base-mark, 5,523,370 cubic yards.

No. 2 might be formed in Cherry Creek by throwing a dam across it above its mouth. The dam should be 40 feet high, and the length of its feeder sixteen miles. For this and all the following reservoirs we shall allow the same data, 6 feet water above the base-mark and 6 inches descent per mile for their feeders. Area, 1,752,000 square yards; prism, 3,170,148 cubic yards.

No. 3 might be formed on Youghiogheny, between Cherry and Snowy Creeks, by throwing a dam through it above the mouth of Snowy Creek. Height of the dam, 50 feet; length of the feeder, fourteen miles. Area, 1,475,444 square yards; prism, 2,796,518 cubic yards.

No. 4, receiving Laurel Creek and Snowy Creek, might be formed by throwing a dam across the latter above its mouth. Height of its dam, 50 feet; length of its feeder, fourteen miles. Area, 3,444,444 square yards; prism, 6,536,666 cubic yards.

No. 5 might be formed in the Great Youghiogheny, between Snowy Creek and the Little Youghiogheny, by throwing a dam across it above the mouth of the Little Youghiogheny. Height of the dam, 67 feet; length of the feeder, ten and a half miles. Area, 2,833,332 square yards; prism, 5,555,555 cubic yards.

No. 6 might be formed in the Little Youghiogheny by throwing a dam across its mouth. Height of the dam, 67 feet; length of the feeder, eleven miles. Area, 53,375 square yards; prism, 106,750 cubic yards.

No. 7 might be formed in Dunker's Lick, by throwing a dam across it, above its mouth. Height of the dam, 75 feet; length of the feeder, nine miles. Area, 1,055,555 square yards; prism, 1,851,851 cubic yards.

No. 8 might be formed in the Great Youghiogheny, between the mouth of the Little Youghiogheny and the ledge, by throwing a dam across the ledge. The height of this dam, $94\frac{3}{8}$ feet; length of the feeder, six and a half miles. Area, 2,770,666 square yards; prism, 5,303,555 cubic yards. Area of all the reservoirs, 16,279,149 square yards; prism of all the reservoirs, 30,844,413 cubic yards.

If we dispense with the last two reservoirs, whose dams are the highest and most expensive, the five remaining reservoirs above the mouth of the Little Youghiogheny will contain: Area exposed to evaporation, 12,452,928 square yards, or $4\frac{2}{100}$ square miles, or 2,572.80 acres. Prism of their waters, 6 feet above the base-mark, besides

6 inches allowed per mile of the length of the feeder of each reservoir for its descent. These are all available to supply the summit-level 23,689,007 cubic yards.

These reservoirs are all independent of one another, and the higher ones may pour the surplus of their waters into the lower ones. Those numbered 3 and 5 in the Great Youghiogheny may be regarded as one, to which all the others can contribute when circumstances require it. The dam No. 3 might even be suppressed, which would reduce the number of dams to 5, but the proper location of these dams, as also their number and dimensions, will receive further investigation, which belong to the final project; their number will likely be reduced.

As to the total quantity of water which these basins might hold, if we suppose their mean depth 16 yards, and a middle horizontal section run between the surface and bottom, equal in area to one-half of the upper surface, or to 6,226,464 square yards, (half of 12,452,928 square yards,) it will amount to 99,623,424 cubic yards, or, in round terms, 100,000,000 cubic yards.

As to the time necessary to fill them, from observations taken with care, from 1817 to 1824, inclusive, by Mr. Lewis Brantz, in the vicinity of Baltimore, Md., we have the following results: In the course of eight years, from 1817 to 1824, there fell, on a mean average, yearly, 39.89 inches. In 1822 there fell the smallest quantity. The summer was very dry, vegetation deficient; the crops of grain were short. The quantity of rain which fell that year was 29.20 inches. The greatest quantity which fell was in 1817. It amounted to 48.55 inches. Applying these data to the country round the summit-level, and using only the results of the year 1822, the rain which fell in the first three and last three months of this year amounted to 16.70 inches, while that which fell in the same months of the year 1817 amounted to 18.40 inches. These 16.70 inches are equivalent to 0.465 cubic yards. Thus, during the first three and last months of each year, there will fall at least 0.46 cubic yards of rain on each square yard of the heads of the Youghiogheny, and an area of 217,391,304 square yards would be required to collect water for filling the 100,000,000 cubic yards of the reservoirs. This area amounts to 70.18 square miles; and the area of the valleys of the two Youghioghenies, above their junction, and the surface of the reservoirs amounts to much more. Besides, the heads of Cheat River could, perhaps, be brought to feed the reservoirs. These reservoirs once filled, the mass of waters which lies lower than the head of the feeders will never alter, and the upper part, which feeds the summit-level, will alone require to be renewed every year. We have seen that it contains 23,689,007 cubic yards.

The least quantity of water which the Great Youghiogheny gave in 1824, under the bridge on the road from Mansfield to Morgantown, was on the 21st of September—22.58 feet in a second. The little Youghiogheny gave, on the 23d of September, 1824, at German bridge, 4.30 feet. Total given by those two streams in a second, at their lowest stage, 26.88 feet.

This is the minimum which they can give to supply the reservoirs. In one month it would amount to 2,580,480 cubic yards, and supposing, what is most unlikely, that the two Youghioghenies and their tributaries should remain in this state, and give no more for six months, from May to October, it would supply the reservoirs with 15,482,880 cubic yards; and as during the six preceding months they would have received much more, they would be full at the opening of navigation, and receive every month at least 2,580,480 cubic yards as regular tribute.

We do not consider in this calculation the loss by filtration and evaporation, for by raising the dams of the reservoirs, a quantity of water would be added to them, which would overbalance it.

We must now compare those supplies, the minimum of what the heads of the two Youghioghenies can furnish, with the maximum of what either of the two summit-levels will require.

They will both require the same expense of water for lockage. We know that two lockfuls is the maximum expense for raising or lowering a boat, and eight minutes are required for its passage through a lock of 30 yards in length, 5⅓ yards in breadth, and 2⅔ yards in lift. Such a lock will contain 426.66 cubic yards, without deducting from it the draught of water of the boat, and its passage (at the maximum) will thus consume 853.32 cubic yards, or 854 cubic yards at most. Now, if the canal is navigated nine months, or two hundred and seventy days a year, at ten hours a day, and that the locks of the summit-level be kept in constant operation all that time, they might pass, allowing eight minutes for each boat, 20,250 boats, at an expense of water equal to 17,293,500 cubic yards for the nine months, or 1,921,500 cubic yards a month. This maximum of water for the expense of lockage is 658,980 cubic yards less than the minimum which the reservoirs will receive during that time.

The expense of water for lockage being 17,293,500 cubic yards, and the reservoirs containing 23,689,007 cubic yards, there will remain in reserve to supply the losses of the summit-level from filtrations and evaporation, 6,395,507 cubic yards.

The summit-level of Deep Creek, extending eleven and three-quarter miles in length, will require 413,600 cubic yards to fill it; and supposing that it loses by filtrations and evaporation the value of its prism every month, or nine times in the year, it will expend 3,722,400 cubic yards. The profile of its feeder having a supposed area of 10 square yards, and a length of ten and one-half miles, it will consume, at the same rate, 1,663,200 cubic yards. Total consumption for nine months, 5,385,600 cubic yards. Retrenching this quantity from the surplus mass of the reservoirs, there will still remain 1,009,907 cubic yards, which, after supplying all the waste of lockage and the losses of the summit-level from filtrations and evaporation, will serve as an additional supply to repair those of the eastern and western branches of the middle section.

The Youghiogheny summit-level, extending twenty-one miles in length, will lose, from filtrations and evaporation, on the same principle, 739,200 cubic yards a month, (the value of its prism,) and 6,652,800 cubic yards in nine months. It would thus absorb the whole surplus mass of the reservoirs, after the waste of lockage, and require a much greater expenditure of water than the Deep Creek summit-level.

Thus the important advantages of a greater supply of water, of a length shorter by nine miles, of a tunnel shorter by two and a half miles, render the Deep Creek route superior to the other; though the final surveys only can settle that point, yet at this stage of our operations we would recommend that route in preference. However, the analysis which we have just concluded is a convincing proof that a canal by either of those routes over the chain of the Alleghanies, between the mouths of Savage River and Bear Creek, is perfectly practicable. The total distance from the mouth of Savage River to that of Bear Creek will be forty-one miles at least; the rise from the mouth of Savage River to the base-mark, 1,432 feet; and the fall from the base-mark to the mouth of Bear Creek, 956.35 feet; total of lockage, 2,388.35 feet.

The preparatory surveys executed on this middle section were performed by Captain McNeill, of the United States Topographical Engineers, and Mr. Shriver, assistant civil engineer, employed by the United States. The talents and activity displayed by these gentlemen and their assistants enabled the board to collect the facts on which they rest their opinion of the practicability of this middle section, and of the best direction through which its route can be directed.

Captain McNeill was assisted in these labors by Messrs. De Russy, Cook, Trimble, Hazard, Dillahunty. Fessenden, and Williams, lieutenants of artillery, whose scientific education, imbibed in the Academy at West Point, was thus made valuable in the most efficient and useful manner to their country and to themselves. Mr. Shriver was assisted by Messrs. Jonathan Knight, John S. Williams, Freeman Lewis, and Joseph Shriver. The memoirs, surveys, and maps of these gentlemen accompany this report.

Before we conclude the article relating to this middle section, we should give an analysis of two other routes which have been proposed for leading the canal over the Alleghany; the one by ascending Will's Creek, (a stream which falls in the Potomac at Cumberland,) and descending to the Youghiogheny by the valley of Casselman's River; the other by passing from the valley of the Potomac to that of Cheat River, and thus descending to the Monongahela.

First. Two of the head springs of Will's Creek rise very near Flaugherty Creek, which falls in Casselman's River, below Salisbury; the eastern is called Laurel Run and the other Shock's Run. The shortest distance between Laurel Run and Flaugherty Creek is one mile 756 yards. It was measured from Wilhelm's saw-mill, on Laurel Run, to Engle's saw-mill, on Flaugherty Creek. The first is 156 feet lower than the second. A deep cut of 333 yards long and 35 feet deep, in the highest part of it, on the side of Engle's saw-mill, a tunnel of 1,483 yards, and another deep cut 700 yards long and of the same depth as the former, on the side of Laurel Run, would be required to unite those two streams. The greatest height of the ridge above the bed of the tunnel would be 156 feet. This route offers great advantages if we only considered the shortness of the distance and tunnel; but as to the essential condition of a sufficient supply of water, it is absolutely out of the question. Flaugherty's Creek, at Engle's mill, gives only 0.415 cubic foot in a second, and Laurel Run, at Wilhelm's mill, 0.600 cubic foot, (at their lowest stage in 1824.) They would only give, together, 1.015 cubic feet per second to feed the whole summit-level. The details, which we have already given in analyzing the Deep Creek route and summit-level, are sufficient to show the impracticability of running a canal by the route of Flaugherty's Creek with so small a supply of water.

As to the route between Shock's Fork and Flaugherty's Creek, the season was too advanced to measure accurately its length, or the tunnel and deep cuts which it would require.

Their profile will be surveyed next season. This route would be longer than the other, and its summit-level should be fed by the waters of Castleman's River above Salisbury, led by a feeder to the western extremity of the tunnel. This feeder, following the eastern side of Castleman's Valley, would receive the waters of its tributaries between Salisbury and Flaugherty's Creek. At their lowest stage these tributaries gave, altogether, 5 feet in a second, and Castleman's River, above Salisbury, 15.33 cubic feet; total, 20.33 cubic feet to feed the summit-level. This quantity is not considerable when we consider that, on a length of thirty miles from the summit-level to Cumberland, the canal would have to draw most of its water from Castleman's River, for Wills Creek is a torrent, which, in the greatest part of its course, gives but little water in summer. The length of this summit-level, and of the route which the canal would thus trace, are less than by Deep Creek. As to their comparative heights, no survey was made in the season of 1824 to ascertain the difference. We shall now expose the reasons why the western branch of the canal was not led through the valley of the Monongahela, (before concluding this part of our report.)

We have already seen that the valley of Cheat River, through which it would be necessary to pass to the Monongahela, is divided from the Upper Youghiogheny by a ridge whose greatest depression, at the head of the two Muddy Creeks, is 226.77 feet above the level of the base-mark. A tunnel would, therefore, be necessary to pass from the valley of the Youghiogheny to that of Cheat River.

A single inspection of the map will show that the route of the canal would be very much lengthened by running its summit-level from the heads of the North Branch of the Potomac to those of Cheat River, and that it should be raised to a much higher level than on the route of Deep Creek. There is every reason to believe that the bed of Cheat River has a more rapid descent than that of the Youghiogheny; and that where it forces through the Laurel Hill, it is already nearly on a level with the Youghiogheny at Connellsville, for at this gap and a little above Furnace Run it begins to be navigable. Its bed is here about 150 yards wide. The highest floods in Cheat River do not rise above eight or ten feet at Furnace Run, and at its lowest stage in August and September it is very low at this place, and often fordable. Indeed, Cheat River to its junction with the Monongahela receives no stream of any importance but the Big Sandy, whose supply is constant, but in the summer is very trifling, even toward its mouth and in the lower part of its course. After descending along a rocky and very precipitous bed, Cheat River mingles its clear and limped waters with the muddy stream of the Monongahela, whose bed and shores are all formed of alluvial soil.

The Monongahela has absolutely the same features as the Ohio; its shores are flat. but raised perpendicularly along both sides of the river to the height of 15 or 25 feet above the line of water, formed of a rich alluvial soil. They are covered by the current, and when the river rises they crumble into it and render its waters muddy. The floods of the Monongahela are considerable. At Brownsville it rises 38 feet, while at its lowest stage its depth is only from 12 to 15 inches on its highest bars. The two banks present all along a succession of flats and bluffs. The flats of one bank are generally opposite to the bluffs of the other, and the former are found where the river expands, while the latter close on its banks where it narrows. The chief tributaries of the Monongahela are on its right shore: George's Creek, below Mr. Gallatin's residence; Big Redstone, below Brownsville; and on the left, Ten-Mile Creek. These streams flow constantly, but in summer give but a small quantity of water; an observation which is also applicable to many of the tributaries of the Youghiogheny.

If the western section of the Chesapeake and Ohio Canal cannot be led to the Monongahela, it will at least embranch with it at McKeesport, and perhaps, when a denser population will render it desirable, a line of junction may be drawn between Cheat River and the Valley of Youghiogheny. It would be fed by a reservoir above the gap of Cheat River and the constant springs which run from the western ridge of Laurel Hill.

WESTERN SECTION.

This section begins at the mouth of Bear Creek and ends at Pittsburgh, descending the valleys of the Youghiogheny and Monongahela to the Ohio.

From the mouth of Bear Creek to that of Castleman's River the Youghiogheny runs in a very winding course between a succession of flats and bluffs, the flats of one shore being generally opposed to the bluffs of the other; the banks high and rugged where they wind in, and flat where they wind out. The two banks present nearly the same difficulties. The right shore, however, seems the best. The distance between those points, following the winding of the river, is about sixteen and a half miles.

Castleman's River is about one hundred yards wide at its mouth. It is a fine river, and will give a great deal of water to the canal. At the driest season it offers from inches to 1 foot in depth. Before joining the Youghiogheny it receives Laurel Hill Creek.

From the mouth of Castleman's River till you reach two or three miles above Connellsville, the Youghiogheny forces through Briery Mountain and Laurel Hill, and its bed is very deep. The left bank is very high and rugged, the right somewhat less. In this space of about twenty-eight and a half-miles the canal must be frequently cut in a shelf on the sides of the valley, or run on embankments supported by a wall. The river has a fall of about 16 feet at Ohiopyle Falls; it is here about 150 yards wide.

Connellsville is considered as the head of navigation in the Youghiogheny. In the driest season it has here from 8 inches to 1 foot in depth.

From Connellsville to Robstown the river winds during twenty-four or twenty-five miles. On all this extent the right bank is far preferable to the other. Except in three or four places, where you meet with bluffs, it consists of flats or gentle slopes, where the canal can be run without difficulty. As to these bluffs, they consist of schistose rock, easy to work. The only stream of any importance which joins the Youghiogheny between Connellsville and Robstown is Jacob's Creek, and it gives but little water in dry seasons. That route is also intercepted by two or three deep ravines, which the canal must cross on aqueducts.

The distance between Robstown and McKeesport is about sixteen miles. Along this route the right shore remains preferable to the other; it consists of a succession of flats and spurs, which, being of a schistose nature and moderate height, will offer no considerable obstructions to the canal.

From McKeesport to Pittsburgh the right shore of the Monongahela offers a most favorable ground, except along the two spaces of about a mile each, where rugged bluffs close on the river. The first is below Judge Wallis' and the field of Braddock's defeat; the second before reaching Pittsburgh. The whole distance, in following the right bank of the river, is between McKeesport and Pittsburgh, from fifteen to sixteen miles.

The highest floods of the Youghiogheny occur between Castleman's River and Connellsville; they rise to 18 feet. At Connellsville they rise from 12 to 15 feet. Salt-wells may be dug in its valley; coal and iron are abundant; and excellent materials for building, timber and stone, are found all along it.

The preparatory surveys of this western section were not commenced during the last season, 1824. They can alone fix the general route of the canal; they will be directed on the following bases: From Bear Creek the canal must follow the right shore of the valley, descending along the Youghiogheny; and, though it is most favorable, (presenting a rugged bank only for four or five hundred yards,) when it reaches Selbysport bridge two lines of direction may be tried, one along the right and the other along the left bank, to the old salt-works. The depth and breadth of the valleys and ravines, which it will be necessary to cross on aqueducts, will be measured, and the location of these aqueducts and of the dams to form reservoirs will be fixed. If between Selbysport and the old salt-works the left shore presents any advantages over the other deserving the expense and trouble of crossing twice the Youghiogheny, the location and dimensions of two aqueducts, one at Selbysport and above the old salt-works, will be determined, and a feeder led from Castleman's River to the latter.

From the old salt-works to the Ohiopyle Falls the canal must follow the right shore, which is most favorable, and then, crossing Indian Creek on an aqueduct, continue along the same bank to the paper-mill, four or five miles south of Connellsville. It will be proper to ascertain whether its line should not leave the valley of the Youghiogheny above the Ohiopyle Falls, and, running east, gain the southern branch of Indian Creek, to rejoin the Youghiogheny by descending Indian Creek Valley.

From the paper-mill the canal should be run at a sufficient elevation above the river to leave the shore, and gain, if possible, the high level which lies east of Connellsville, in order to turn round the rugged bluff below that place. From thence, following the right shore, it will reach Robstown, after crossing on aqueducts Maunet's Creek and Jacob's Creek. The localities and dimensions of these aqueducts must be determined, as well as the resources which these streams may afford to supply the canal by turning them into reservoirs.

From Robstown to McKeesport, keeping along the right shore, it must cross Sewickly Creek over an aqueduct, whose dimensions and location must be determined. As this creek has two considerable branches, they must be examined to determine whether reservoirs cannot be made in them. From McKeesport to Pittsburgh the canal will follow the right shore of the valley of the Monongahela, crossing in succession Crooked Run, Turtle Creek, and Nine-Mile Run on aqueducts.

To ascertain whether from the paper-mill the right shores of the Youghiogheny and Monongahela are certainly the best, a level should be run along their valleys on the left shore, and the locations and dimensions of the dams or aqueducts which it would be necessary to run through the Youghiogheny at McKeesport and through the Monongahela near its confluence with the Youghiogheny, in case this route was adopted, should be fixed and calculated.

It will also be essential to try whether the canal might not turn to the west of that narrow and rugged portion of the valley of the Youghiogheny where it forces its way through Briery Mountain and Laurel Hill. For this purpose a level should be run from Selbysport and some point of a proper elevation, and cross the Briery Mountain at the depression which it offers between the heads of Buffalo Marsh Run and the eastern branch of Sandy Creek. This level should then wind round the ravines of the head of the western branch of Sandy Creek till it met the Laurel Hill at the spot where it might be crossed by the shortest tunnel. When it reaches its western slope it should run northwardly along its foot, to descend by one of its ravines to the Youghiogheny opposite the paper-mills.

On the whole, the western section of the canal, from the mouth of Bear Creek to that of the Monongahela at Pittsburgh, offers no obstacles which may not be surmounted at a reasonable expense; and the waters of the Youghiogheny, Bear Creek, and Castleman's River are amply sufficient to feed it. Large reservoirs may be formed in Bear Creek and Castleman's River by throwing dams across them, and on the route from Castleman's to the paper-mills, and at the mouth of the Youghiogheny in the Monongahela. The practicability of this section is out of the question.

Its length will be about one hundred miles, and its descent from Bear Creek to Pittsburgh 584½ feet, as Pittsburgh is 756 feet above the level of the ocean. The investigation of the topography and water-courses of the country through which the Chesapeake and Ohio Canal should run, and the results of our preparatory surveys, obtained up to the present moment, demonstrate that this noble enterprise is practicable; and, although we have not yet sufficient data to calculate the expense of the work, there is every probability that it will not bear any comparison with the political, commercial, and military advantages which it will procure to the Union.

The total result of the length, rise, and fall of the canal is as follows:

Total tength:

	Miles.
From the tide-water in the Potomac to Cumberland, (from Messrs. Moore and Briggs' survey)	182
From Cumberland to the mouth of Savage River, (from report of Major Abert, United States Topographical Engineers)	27½
From the mouth of Savage River to that of Bear Creek, by the Deep Creek route, from the surveys of Captain McNeill, United States Topographical Engineers, and Mr. Shriver, United States assistant civil engineer)	41
From the mouth of Bear Creek to Pittsburgh, (from Mr. Shriver's computation)	100
	350½

Total rise:

	Feet.
From tide-water in the Potomac to Cumberland, (from the profile of Cumberland road)	537
From Cumberland to the mouth of Savage River, (from Major Abert's survey)	327½
From the mouth of Savage River to the base-mark on the Deep Creek summit-level,(from Captain McNeill's survey)	1,432
	2,296½

Total descent:

	Feet.
From the base-mark to the mouth of Bear Creek	956
From thence to the Ohio, at Pittsburgh	584½
	1,540½
Total lockage for rise and descent	3,837

* * * * * * *

S. Bernard,
Brigadier-General.
Jos. G. Totten,
Major Engineers, and Brevet Lieutenant-Colonel.

REPORT OF THE BOARD OF INTERNAL IMPROVEMENT ON THE CHESAPEAKE AND OHIO CANAL, COMPRISING THE PLAN AND ESTIMATE OF THE SAME, OCTOBER 23, 1826.

The operations which have been executed in the field in 1824 in relation to the contemplated Chesapeake and Ohio Canal had chiefly for object to ascertain the practicability of the undertaking. Those performed in 1825 were to determine the route to be recommended, as also to obtain the data necessary to frame a general plan of the work and a preparatory estimate of the expense.

Another series of operations remains yet to be executed: 1. To locate accurately the canal on the ground, and to fix the final site of the locks, aqueducts, culverts, dams, bridges, &c. 2. To frame for each portion of canal the plans and profiles necessary for its execution. 3. To make on the spot the calculations of excavation and embankment. 4. To draw up the estimate of each individual work according to local circumstances. 5. To prepare the proper specifications to put the work under contract. This series of operations belongs more properly to the construction than to the general plan of the canal, and may be deferred until the execution shall have been decided. These operations will then keep pace with the execution of the work, and their results for each portion will improve by the experience gradually acquired during the construction of the canal.

These considerations, the scarcity of means at our disposal at this time, and the expediency of affording a result as to this great important national work, have induced us to limit the surveys to those strictly necessary to enable us to frame a general plan and a preparatory estimate.

In the report submitted by the board on the 2d of February, 1825, (marked A among the documents which accompanied the President's message of the 14th of February, 1825,) all the experimental lines surveyed in 1824 have been described, and mention has been made of several others which were yet to be surveyed. We have also presented, in the same report A, the considerations relative to the hydrography of the country in the general direction of the canal. We will, therefore, confine ourselves to the description of the experimental lines, which, on account of the advanced season in 1824, had been postponed to 1825; we will compare these lines to the others, and point out the route which seems to us entitled to preference.

EXPERIMENTAL LINES.

Summit-level by Deep Creek.—In the report A, it had been anticipated that the section of canal from the tunnel at Dewickman's Arm to the mouth of Bear Creek would follow the valley of Deep Creek as far as the Rapids, then turn Panther's Point, and descend to the mouth of Bear Creek, along the left side of the Youghiogheny. However, it became necessary to compare this route with another more direct, which, following the former as far as Deep Creek bridge, would continue to Rock Creek Run, a western tributary of Bear Creek. The survey has shown that, the bottom of canal being assumed three feet above the bottom of Deep Creek at the bridge, a tunnel would be necessary to cross the ridge which separates Buffalo Marsh Run from Rock Lick Run. The distance and descent are as follows:

Sections.	Miles.	Yards.	Feet.
From the eastern end of the tunnel at Dewickman's Arm to the base-mark at Deep Creek	6	1,048	
Descent in this distance			
From the base-mark to the debouch into Rock Lick Run	5	38½	
Descent in this distance			
From this debouch to the mouth of Bear Creek	7	535½	
Descent in this distance			912
Total	18	1,622	912

In this total distance, two tunnels would be necessary: one at Dewickman's Arm, whose length would be one mile 568 yards, and whose bottom would be below the top of the ridge 233 feet; one at Buffalo Marsh Run, whose length would be two miles 254 yards, and whose bottom would be below the top of the ridge 343 feet; total length of tunnels three miles 822 yards.

In order to remove all doubts as to the expediency of this portion of canal-route, and to lessen, as much as practicable, the length of the tunnels and the excavation at their deep cuts, a second line, 13 feet 9 inches higher than the preceding one, has been tried; the results of which are as follows:

Sections.	Miles.	Yards.	Feet.
From the eastern end of the tunnel at Dewickman's Arm to the base-mark at Deep Creek bridge	7	216	
Descent in this distance			
From the base-mark to the debouch into Rock Lick Run	5	38½	
Descent in this distance			
From this debouch to the mouth of Bear Creek	7	535½	
Descent in this distance			925¾
Total	19	790	925¾

As to the length of the tunnels and the height of the ridges above the bottom of tunnels, they are respectively:

Sections.	Miles.	Yards.	Feet.
Dewickman's Arm, length	1	278	
Height of the ridge			219¼
Buffalo Marsh Run, length	1	1,215	
Height of the ridge			329¼
Total	2	1,493	

This arrangement would lessen the length of tunnels by 1,089 yards, and also the excavation through the valley of Deep Creek by at least 1,000,000 cubic yards. But the level of this route being 13¾ feet higher than that of the former route, the volume of available water in the reservoir of Deep Creek would be much diminished, and it would also become necessary to raise, by 13¾ feet, the dams recommended (in the report A) across the Youghiogheny, in order to feed the canal; a circumstance which would increase the expense and difficulty attending the erection of these dams. It must be observed that Deep Creek alone is altogether unable to feed a summit-level, while it scarcely yields, during the dry season, 5 cubic feet of water per second. Its tributaries are liable to become entirely dry, as happened in 1825.

However, we will compare this direct route, running from Dewickman's Arm to the mouth of Bear Creek, with that through Deep Creek and the right side of the Youghiogheny, and whose distance and descent are as follows:

Sections.	Miles.	Yards.	Feet.
From the eastern end of the tunnel at Dewickman's Arm to the base-mark at Deep Creek bridge	6	1,048	.....
Descent in this distance	....	....	.....
From the base-mark to the western end of the summit-level	6	204¾	.....
Descent in this distance	....	....	.....
From the western end of the summit-level to the mouth of Bear Creek	15	100	.....
Descent in this distance	....	....	912
Total	27	1,352¾	912

On this portion of route there would be one tunnel only, (at Dewickman's Arm,) whose length, as already stated, would be one mile 568 yards. The distance and descent in following the direct route would be, as above, nineteen miles 790 yards 925¾ feet.

The length of the two tunnels taken together would be, as above, two miles 1,493 yards.

The direct route would, therefore, be eight miles 562¾ yards shorter than the other, but it would require a greater length of tunnel by one mile 568 yards, and cause an increase of lockage of 27½ feet, which, as to time and expense, gives a decided advantage to the other route. Again, the descent from the debouch into Rock Lick Run to the mouth of Bear Creek is 925¾ feet, on a distance of seven miles 535½ yards, which, on the supposition of a uniform declivity, could afford but 115 yards to the location of one lock, 8 feet lift, with its adjoining pond; but this declivity is far from being uniform, and in some places it will be so rapid as to oblige to locate the locks quite close to each other, a circumstance which would involve the expense of a double set of locks. All these considerations, added to the difficulty of feeding the upper level, induce us to reject this direct route, and to give the preference to that through the valleys of Deep Creek and of the Youghiogheny, as assumed in the report A, (February, 1825.)

Summit-level by Flaugherty Creek.—But a much more important route was yet to be examined, which, having its summit-level at the source of Will's Creek, would commence at Cumberland, ascend this creek, cross the ridge which separates Will's Creek from Castleman's River, and descend the valley of this stream to debouch into the Youghiogheny at its junction with Castleman's River and Laurel Hill Run. Mention has been made of this route in report A, (pages 40 and 41.) Some experimental lines were surveyed on the summit-ground in 1824, and some measurements of water were taken; but the season being then too far advanced to prosecute further the surveys and levelings relative to this route, the board were compelled to defer their execution until 1825; and as early as the 12th of March, 1825, they framed detailed instructions respecting the surveys and investigations necessary to ascertain the practicability of a route of canal in this direction. This route deserved so much the more a careful examination that it promised, by means of a tunnel, a shorter distance, but it became necessary to ascertain, in the first instance, the minimum length of the tunnel which should receive, at its western end, water enough from Castleman's River to supply the summit-level and a portion of the canal down Will's Creek. Upon this point rested the practicability of this route. Indeed, the survey made in 1824 had tried a tunnel of 1,483 yards in length, with a greatest height of ridge of 156 feet; but the essential condition of a sufficient supply of water had not been obtained at such an elevation. It therefore remained to find out, by surveys, a tunnel combining the shortest length with a competent supply of water. These surveys were intrusted to Capt. Wm. G. McNeill, of the Topographical Engineers, who carried them, in the most able manner, into execution.

The result has been that a tunnel from the mouth of Bowman's Run, in Will's Creek, to the mouth of Flaugherty Creek, in Castleman's River, was the shortest which could be admitted to procure at the same time the other requisite as to the sufficiency of water. The length of this tunnel is four miles 80 yards, with a deep cut at each end; the eastern being 140 yards long, the western 1,060 yards; the greatest depth of each 35 feet, but the height of the top of the ridge above the bottom of the tunnel is not less than 856 feet.

Let us now examine the resources afforded to feed this summit-level. Castleman's River is the only stream upon which we can rely to fulfill this object. It yielded, on the 21st of June, 1825, at Pleucher's farm, twelve miles above the mouth of Flaugherty Creek, 18 cubic feet of water per second; on the 7th of the same month, it yielded at the same place 44 cubic feet per second; on the 10th of July, same year, it yielded 38 cubic feet per second, above the mouth of Flaugherty Creek. It must be observed, that in consequence of a freshet, the stream, on the 24th of June, 1825, yielded at Forney's Mill, five miles above Flaugherty Creek, 803 cubic feet per second; three days afterwards it still delivered 103 cubic feet. From all these results we adopt the smallest; and we assume 18 cubic feet as the minimum of water supplied by Casselman's above the mouth of Flaugherty Creek. Besides this supply of running water, two reservoirs can be made in the bed of the stream: one at Pleucher's farm, containing 4,679,029 cubic yards; the second, below Forney's Mill, containing 17,091,490 yards; together, about 22,000,000 yards. The dam of the first would be 40 feet high, 230 yards long at the top; the foot 114 feet above the summit-level; the dam to form the other would be 50 feet high, (to obtain a height of 40 feet of available water,) and from 140 to 160 yards long at the top. The feeder from the upper reservoir to the lower one would be about seven miles; but the feeder from the lower and larger reservoir to the summit-level would be three and one-third miles only. The area of the reservoir at Pleucher's farm will be 1,040,600 square yards; that of the great reservoir, 2,541,000 square yards; total, together, 3,581,600 square yards.

We shall, in the sequel of this report, take into more minute consideration these supplies of water; for the moment we leave the subject to present a comparison between this route of canal and that by Deep Creek, as suggested in the report A, by and in consequence of the limited facts which then it had been in our power to ascertain. The first will be designated Castleman's route, the other Deep Creek route.

The length, ascent, and descent of Castleman's route are as follows:

Sections.	Miles.	Yards.	Feet.
From Cumberland bench-mark to the eastern end of the summit-level	29	240	
Ascent in this distance			1, 325
Summit-level: eastern basin, 880 yards; eastern deep-cut, 140 yards; tunnel, four miles 80 yards; western deep-cut, 1,060 yards; western basin, 880 yards	5	1, 280	
From the western end of the summit-level to the Youghiogheny, 440 yards below the mouth of Castleman's River	35	1, 250	
Descent in this distance			636
Total distance and lockage	70	1, 010	1, 961

The length, ascent, and descent of the Deep Creek route are as follows:

Sections.	Miles.	Yards.	Feet.
From Cumberland bench-mark to the mouth of Savage River	30	350	
Ascent in this distance			327½
From the mouth of Savage to the mouth of Crabtree Creek	5		
Ascent in this distance			383
From the mouth of Crabtree Creek to the eastern end of the summit-level	8	1, 430	
Ascent in this distance			1, 051
Total ascent, 1,761½ feet.	44	20	1, 761½
Summit-level: eastern deep-cut, 352 yards; tunnel, one mile 568 yards; western deep-cut, five miles 480 yards; western end, six miles 204⅔ yards	12	1, 604⅔	
From the western end of the summit-level to the mouth of Bear Creek	15	100	
Descent in this distance			912
From the mouth of Bear Creek to a point in the Youghiogheny 440 yards below the mouth of Castleman's	16	1, 075⅓	
Descent in this distance			164
Total descent, 1,076 feet.			
Total distance and lockage	88	1, 040	2, 837½

Both summits of these routes, being compared as to altitude to the Cumberland bench-mark, will show a difference of level of 436½ feet in favor of the Castleman route. This difference would be 440 feet, if the level of comparison were assumed at the point of junction of these routes into the Youghiogheny; but as at this point no well-fixed bench-mark had been agreed to between the two surveying parties, we rely in preference, on the former result. This important result shows that through Castleman's the lockage will be 873 feet less than through the other route.

As to distance, the foregoing statements exhibit a length of eighteen miles 30 yards in favor of the Castleman route; which, combined with a less amount of lockage, gives to this route, as to time, a decided advantage over the Deep Creek route.

Let us examine now which of these routes will afford the greatest facility to the location of the locks.

By assuming 8 feet as a common lift, we find that, from Cumberland to the mouth of Savage, the average distance between the heads of the two locks will be 1,296 yards; from the mouth of Savage to Crabtree Creek, 183 yards; from the mouth of Crabtree Creek to the eastern end of the summit-level, 117 yards; and this on the supposition of a uniform declivity, which is far from being the case, and more especially in the valley of Crabtree Creek, where, toward the head, the locks, on account of the steepness of the ascent, could not even find room, unless their lift should be considerably increased. To this difficulty we must add the narrowness of the valley, which would oblige to resort to very extensive means to erect, where necessary, double sets of locks, as also to shelter the work from destruction, either by high freshets or by heavy showers.

As to the western section of this route, serious difficulty would be encountered to turn Panther's Point, the sudden fall being great and the side of the valley very precipitous. It would become necessary to descend at once about 400 feet in a distance which could hardly afford room for the location of locks succeeding closely to each other without intermediate ponds. This circumstance would either necessitate a double set of locks, or oblige to stretch, at considerable expense, the line of canal around this steep spur which separates Deep Cut from Hoy's Run.

These difficulties as to the location of locks are not to be met with on the Castleman route. In the valley of Will's Creek 200 yards will be the shortest distance between the heads of two successive locks, and in that of Castleman's 300 yards. We must also remark that, though the valley of Will's Creek becomes gradually narrower above the mouth of Little Will's Creek, yet it affords room enough for the works, and these will be more easily protected against freshets and showers than they could be in the valleys of Crabtree Creek and Savage River.

The foregoing considerations show that, in relation to a less difficult location of canal, the Castleman route has (abstraction being made, for the present, of the tunnel) a decided advantage over the Deep Creek route. But another important object is also to be examined: we mean the supply of water at the respective summit-levels.

Respecting this point, it has been seen that the resources yielded by Castleman's, above the mouth of Flaugherty Creek, consisted of 18 cubic feet per second of running water, and of two reservoirs of available stored water, amounting to about 22,000,000 cubic yards. As to the Deep Creek summit-level, it has been shown in report A (February, 1825,) that Deep Creek delivered, as a minimum, 5.12 cubic feet per second, (page 32;) the Little and Great Youghiogheny together, 26.88 cubic feet per second, (page 38;) total of running water, 32 cubic feet per second.

The reservoirs in Deep Creek amount to 2,214,156 cubic yards of available water, (page 32,) and those in the Youghiogheny to 23,698,007 cubic yards together, (page 37;) total, 25,903,163 cubic yards; we assume 26,000,000. These supplies of water will compare as follows:

	Cubic feet per second.		Cubic yards.
Deep Creek summit, running water...	32	Reservoirs....................	26,000,000
Castleman's summit, running water...	18	Reservoirs....................	22,000,000
Difference in favor of Deep Creek.....	14		4,000,000

But the following remarks will attennate this advantage and induce to place these resources upon a nearer footing: 1. Deep Creek and both Youghioghenies were gauged in 1824, whereas Castleman's River was measured in 1825, whose summer and autumn were drier than those of the preceding year. 2. The feeder destined to bring the water of the Youghiogheny reservoirs on to the summit-level of Deep Creek will be about twelve miles long, while the feeder from the great reservoir below Forney's Mill will be but three and one-third miles in length. Therefore the loss of water by evaporation and leakage will be for the latter the fourth of that for the former. This fact deserves so much more due attention that experience has proved positively that such losses were by far greater in feeders than in portions of canal of the same length. 3. The 18 cubic feet per second allowed to Castleman's River were gauged at Pleucher's farm, 114 feet above the summit-level, and no account has been kept of the water delivered by Meadow Run, Tub Run, Pine Run, tributaries of Castleman's, whose mouths are below Pleucher's farm, and higher than the summit-level; however, they have yielded together, as a minimum, on the last days of June and first days of July, 1825, 13.84 cubic feet per second. 4. The reservoirs in the Youghiogheny present to evaporation an area of (report A, page 37) 12,452,928 square yards, while those in Castleman's present but 3,581,600 square yards; difference in favor of the latter, 8,871,328 square yards, a difference which will cause a saving of about 6,000,000 cubic yards of water, the yearly fall of rain being supposed to be but 36 inches, and the common ratio of 5 to 3 being admitted between the yearly evaporation and fall of rain upon the surface of a given reservoir.

The foregoing facts and computations lead us to the conclusion that, with respect to water-supply, both routes may be considered as on an equal footing. It remains now to compare the expense attending the construction of either route.

The lockage on the Deep Creek route is 873 feet more than on the Castleman route; to which are to be added, for double set of locks in Crabtree, at least 350 feet, and at Panther's Point, at least 200 feet; total, 1,423 feet, or 178 locks, 8 feet lift, which would cost $2,136,000, at the rate of $12,000 each.

The deep cut, from the western end of the tunnel to the base-mark at Deep Creek bridge, is five miles 480 yards long, and has, at its eastern end, a depth of 40 feet, which diminishes gradually on approaching the base-mark. The amount of its excavation will be 1,407,961 cubic yards, from which, on subtracting 87,556 cubic yards, amount of excavation for the western deep-cut of the tunnel at Flaugherty, it remains 1,320,405 cubic yards to the disadvantage of the Deep Creek route. On the reasonable supposition that the ground will require, for excavating, two men, one with shovel, the other with pick, and the transportation being assumed at the distance of ninety yards for an ascent of one-twelfth, this excavation will cost $448,937.70 at the rate of 34 cents the cubic yard.

The Dewickman tunnel is one mile 568 yards long, and has 232 feet of height of ridge above its bottom.

The Flaugherty tunnel is four miles 80 yards long, and has 856 feet of height of ridge above its bottom.

Difference in favor of Deep Creek, two miles 1,272 yards in length, and 623 feet in height of ridge above its bottom.

The comparative cost of these tunnels will be as follows; the substance supposed to be sandstone:

Parts.	Flaugherty's.	Dewickman's.	Difference.
Shafts	$233, 032 95	$17, 108 99	$215, 923 96
Heading	383, 534 83	119, 738 12	263, 796 71
Side-heading	7, 704 27	2, 704 27	5, 000 00
Tunnel	2, 495, 242 80	808, 106 50	1, 687, 136 30
Draining	159, 469 30	7, 010 90	152, 458 40
Total cost	3, 278, 984 15	954, 668 78	2, 324, 315 37

Respecting the dams to be erected across the two Youghioghenies to form the reservoirs destined to supply the Deep Creek summit, they should have at least a height of 50 feet, and may be reduced to four in number. They would also measure together a length of 1,200 yards at the least. As to those across Castleman's, they may be reduced to one only below Forney's mill; its height will be 50 feet, and its length at the top 160 yards. The expense for this object will, therefore, be seven and a half times as great for the Deep Creek as for the Castleman route.

The dam below Forney's mill will cost	$27, 601 60
Therefore the dams across the Youghioghenies will cost together	207, 012 00
Difference in favor of the Castleman route	179, 410 40

Finally, the route by Deep Creek will be eighteen miles 30 yards longer than by Flaugherty Creek. These eighteen miles, on the most favorable supposition of level cutting and light ground, will cost, at the rate of 13.6 cents per cubic yard, digging and transportation included, $96,940.80.

Recapitulating, now, the extra expenses for each route, we find them as follows:

Deep Creek route.

For lockage	$2, 136, 000 00
For the western deep-cut	448, 937 70
For the dams	179, 410 40
For the eighteen miles	96, 940 80
Total	2, 861, 288 90

Castleman's route.

For two miles 1,272 yards of tunnel	2,324,315 37
Difference in favor of this route	536,973 53

The Castleman route will, therefore, be less expensive than the Deep Creek route; its supply of water nearly the same; its location more easy; its summit-level less liable to be encumbered at the ends; and on account of less lockage and shorter length it will produce a saving of time of twenty-two hours. All these results combined lead us to give to the Castleman route a decided preference.

Before closing this part of our report we must exhibit the results of an attempt made to avoid the rugged portion of the Youghiogheny, where the stream forces its way through Briery Mount and Laurel Hill. To this effect a route was tried, which, commencing either at the fork of Bear Creek or above the Swallow Falls, in the Youghiogheny, runs through Asher's Glade, a depression of Briery Mount, thence crosses, by a tunnel, Laurel Hill, to follow afterward its western side, and debouch into the Youghiogheny at the mouth of Dunbar Creek, one mile above Connellsville.

Mention has been made of this route in the report A, (February, 1825,) page 44. Though the single inspection of the ground had sufficiently shown that very little reliance was to be placed upon it, yet it was essential to try its degree of practicability; its surveys and levelings were, therefore, made at as long sights as the ground would admit.

The fork of Bear Creek, that is, the point where the western and eastern branches unite, has been found to be 780.93 feet below the base-mark at Deep Creek bridge, and 640.09 feet below Briery Mount at Asher's Glade; therefore, Asher's Glade is but 131.84 feet below the base-mark at Deep Creek. This fact alone shows the absolute impracticability of obtaining a line of canal in this direction. It shows, also, that whatever may be the line devised to reach Asher's Glade, it cannot be kept lower than 131.84 feet below the summit-level of Deep Creek, and must rely on the Youghiogheny alone for its supply of water; and this for its whole length, from Deep Creek to the mouth of Dunbar Creek; the resources afforded by the intervening streams being, in summer, of no consequence.

By trying a line through the left side of the Youghiogheny, we should first cross this stream by an aqueduct of more than 150 feet high, then follow the western side of the valley, to strike, in succession, the head-branches of Buffalo Creek, Big Sandy Creek, and Little Sandy Creek. The line would then cross Laurel Hill by a tunnel of one and a half miles in length and 547 feet under the ridge, and thence descend to the mouth of Dunbar Creek, after having traversed deep and numerous ravines which furrow the western side of Laurel Hill. It must be remarked that, from the Little Sandy to the mouth of Dunbar Creek, in a distance of about twelve miles, this route of canal would oppose difficulties which would be far greater than those to be met with in the valley of the Youghiogheny, where the stream breaks through Briery Mount and Laurel Hill. The distance from Deep Creek to Connellsville by this route would be seventy-one miles, and six miles longer than through the valley of the Youghiogheny; and if we add to the foregoing statements the deficiency of water, we must conclude that a canal following this direction is utterly inadmissible.

In conformity to an order of the Engineer Department, a leveling has been made, in March, 1826, in relation to a feeder destined to transfer the water-supply of Deep Creek summit to the Casselman summit. Capt. William G. McNeill, of the Topographical Engineers, to whom this duty was assigned, received from the board the necessary instructions. His report affords the following results:

Length of the feeder.

	Miles.	Yards.
From the base-mark at Deep Creek bridge to the point where the feeder meets Castleman's River	15	585
From this point to the bridge across Castleman's River on the National Road, (nearly)	8	880
Thence to the reservoir at Pleucher's farm	1	880
Add the length of feeder from the dams in the Youghiogheny to the reservoir at Deep Creek	12	0
Total length	37	585

On this distance there are four deep cuts and two tunnels, viz:

	Miles.	Yards.
A deep cut terminating in Buffalo Marsh Run	2	757
Thence a tunnel to the valley of Bear Creek	5	939
A deep cut from the end of this tunnel	0	708
A deep cut at the western side of Negro Mountain	0	278
A tunnel through this mountain	1	1,640
A deep cut from the end of this tunnel	0	330
Together	10	1,132

Out of which, for deep cuts, having 35 feet of greater depth, three miles 313 yards for tunnels, seven miles 819 yards.

It is fortunate that so long and so expensive a feeder can be dispensed with.

The foregoing facts and investigations, connected with those exposed in the report A, (February, 1825,) lead us to recommend the following route for the Chesapeake and Ohio Canal:

From Georgetown, D. C., to Cumberland it will ascend the valley of the Potomac; thence the valley of Will's Creek to the mouth of Bowman's Run. It will then cross the summit-ridge by a tunnel, and descend, in succession, the valleys of Casselman's River and the Youghiogheny, to terminate at Pittsburgh, Pa., at the mouth of the Monongahela.

We have now to present the description of the general plan of the work; but as we think it more expedient to progress simultaneously with the description and estimate, we will previously give an analysis of the main prices upon which the estimate is calculated, and point out the dimensions upon which the plan is predicated.

We observe, also, that the whole line of canal will be subdivided into three distinct sections, each of them forming of itself a separate system, viz:

Eastern section, from Georgetown to Cumberland.

Middle section, from Cumberland to the mouth of Casselman's River.

Western section, from the mouth of Casselman's to Pittsburgh.

* * * * * * *

PLAN AND ESTIMATE OF THE CANAL.

The transverse section of the canal is exhibited on the sheet No. 3. The breadth at the bottom is 33 feet; at the surface, 48 feet; the depth of water, 5 feet; the tow-path, 9 feet wide; the guard-banks, 5 feet at the top; the surf-berms, kept on the level of water, 2 feet wide each; the tow-path and top of the guard-bank, 2 feet above the surface of the canal.

This transverse section is to be modified where local circumstances require it, and, more especially, in the cases of deep cutting, steep side-cutting, embanking, and also where the canal is supported by walls. In the framing of the plan a due attention has been paid to these modifications, with a view to conciliate the convenience of the work with the strictest economy. The depth of 5 feet has been preserved throughout the line, but the breadth has been often much lessened. As to the surf-berms, they are intended to protect the slopes from being washed off, as also to lessen the resistance opposed to the boat by affording to the eddy-water a free passage.

We must submit, however, the reasons which led us to propose the above dimensions.

The experiments made in 1775 by the French Academicians (D'Alembert, Condaset, and Bossat) have shown—

1. That the resistance of water to the perpendicular motion of a given plane may be regarded as proportional to the square of the velocity.
2. That the velocity being the same, the resistance of water may be considered as proportional to the area of the plane.
3. That these results obtained only in the case of an indefinite expanse of water.
4. That in narrow canals the resistance increases in a more rapid ratio than the square of the velocity.

To attenuate as much as practicable this inconvenience, researches have been made to ascertain what should be the ratio between the transverse section of the canal and the transverse section of the boat, in order that the boat might move through such a canal as through an indefinite expanse of water.

Experiments made on the subject by the celebrated Chevalier Dubuat have shown that to attain this result the cross-section of the canal ought to be, with moderate velocities, 6.46 times the cross-section of the boat, and the water-line 4½ times the breadth of the boat.

Adopting, to preserve uniformity, 13½ feet for the breadth of the boats used on the Chesapeake and Ohio Canal, (which is the breadth of the Erie Canal and of the Ohio Canal boats,) if we suppose the draught to be 3 feet, the prow to be rectangular, and the sides and bottom of the boat to conform to it, the cross-section of the boat will be 40.5 square feet. Taking, now, this area 6.46 times, we find 261⅝ square feet for the cross-section of the canal, through which the boat would not meet with a greater resistance than through an indefinite expanse of water. The water-line should be 60¾ feet; that is, four times and a half the breadth of the boat.

Were not expense to be taken into consideration, these dimensions might be recommended, but fitness of the work and strict economy must be reconciled as much as practicable, and it is in such a view that smaller dimensions are to be fixed upon.

It is to be remarked that the distance from Georgetown to Pittsburgh in following the line of the canal is three hundred and forty-one and three-quarter miles, which, at the rate of two and a half miles per hour, will be traveled in about 136 hours. The ascent and descent amounting together to 3,158 feet, will require, at the rate of one minute per foot, about 52 hours; distance in time from Georgetown to Pittsburg, 188 hours. Though a number of canals, selected among those executed to this day, might afford, together, the distance and lockage found for the Chesapeake and Ohio Canal, yet there is not, within our knowledge, any line of the same extent requiring even 1,800 feet of ascent and descent taken together. The Erie Canal requires 688 feet for three hundred and sixty-two miles; the line from Liverpool to London, 1,451½ feet for two hundred and sixty-four miles; the canal from the Rhone to the Rhine, connecting Lyons with Strasbourg, has about 1,458 feet of lockage for a length of two hundred miles. The proposed canal has, therefore, as to time, a decided inferiority when compared to a canal of the same length, but having a less amount of lockage; and it becomes, in the present case, indispensable to remedy this inconvenience. The means we propose consist in the increase of the dimensions of the cross-section of the canal, with a view to compensate by a greater weight (transported without additional power) for the virtual increase of distance caused by so great an amount of lockage.

We have shown that this section ought to be 261 square feet, with a water-line of 60 feet, to procure a boat 13 feet 6 inches in breadth the advantage of moving on the canal as on an indefinite extent of water. After many trials and minute calculations, we have concluded to adopt for the contemplated canal the four-fifths of the foregoing results, viz, for the cross-section 208 square feet, and for the water-line 48 feet; and from these data we have framed, with a depth of 5 feet, the general transverse profile of the canal, as exhibited on the sheet No. 3.

Let us now compare this profile to one having 40 feet at the surface, 28 feet at bottom, and 4 feet in depth; the boat used being the same for both, and having 13½ feet in breadth, and 3 feet in draught. We find by calculation that, the velocity remaining the same, the resistance to the boat moving in the 48-foot canal is to the resistance to the same boat moving in the 40-foot canal as 1.21 to 1.58, or as 100 to 130. Therefore, at the same rate of velocity, 100 horses will, on the 48-foot canal, perform the same work as 130 horses on the 40-foot canal; and with the same towing-power the weight transported on the 48-foot canal will be to the weight transported on the 40-foot canal as 130 to 100.

But the depth of the 48-foot canal being one foot greater than the depth of the other, let us examine what will be the comparative resistance of the boat being immersed 4 feet into the 48-foot canal, and but 3 feet in the other. We find in this case the ratio to be 1.47 to 1.58, or 100 to 107, and we infer from it that, with a gain of about 7 per cent. of towing-power, the weight transported on the 48-foot canal will be one-third greater than the weight transported during the same time on the 40-foot canal.

The foregoing considerations show that in determining the transverse section of a canal of great length, and with a dividing summit-level, the amount of lockage must have a due influence upon the breadth and depth of the water-section. And, indeed, taking into view the great distance and considerable lockage belonging to the present case, a cross-section larger than that recommended might have been suggested had not a regard to economy and to a competent supply of water during the dry season forbidden it.

However, the transverse section, as just proposed, may be deemed sufficient to fulfill in a satisfactory manner the main requisite for which it has been intended. And in order to remove all doubt, let us compare as to amount of transportation the contemplated Chesapeake and Ohio Canal with another of the same length, but whose lockage would be 600 feet only, with a transverse section of 40 feet at the surface and 4 feet in depth.

The rate of traveling being supposed for both two and one-half miles per hour, and one minute allowed for each foot of lockage, 60 feet will be, as to time, equivalent to two and one-half miles, and these canals will then compare as follows:

The Chesapeake and Ohio Canal having 3,158 feet of lockage in a distance of three hundred and forty-one and three-quarter miles, is equivalent, as to time, to a single level canal of four hundred and seventy-three miles, which would require 189 hours to be traveled from one end to the other.

The 40-foot canal having 600 feet of lockage in a distance of three hundred and forty-one and a half miles, is equivalent, as to time, to a single level canal of three hundred and sixty-seven miles, and which would be traveled in 146 hours from one end to the other. But it has been shown that on the first canal the amount of transportation being expressed by 130, it will be 100 on the 40-foot canal—the velocity and towing power remaining the same in both cases. Comparing, now, this ratio of 130 to 100 with that of the time employed to travel respectively each canal, viz, 189 hours to 146, it is found that these ratios are equal. Therefore, on either of these canals, and notwithstanding a difference of 2,558 feet lockage, an equal weight will be transported during the same time, and with an equal towing power—a result entirely due to a larger transverse section having been assigned to the canal whose lockage is greater.

With a view to augment still more the amount of transportation without increasing the expense attending it, the boat might have received a length of at least eight times its breadth; but it would have required a length of lock of 118 feet, (between the hollow quoins,) which, on account of the great number of locks, would have caused too great an expense. The necessity of conciliating economy with the object to be expected from the work has, therefore, obliged us to limit the length of the boat to seven times its breadth, 13½ feet—that is to say, to 94 feet about; this length varying, however, from 90 to 94 feet, according to the mode of constructing the boat. With a draught of 3 feet, such a boat, if rectangular, would displace about 100 tons weight of water, or, on account of deviation from this form, about 90 tons only, it will carry a burden of 60 tons. Respecting the locks destined to admit this boat, they must have at least 102 feet between the hollow quoins, and 14 feet breadth in the clear. In the estimate, they are nearly all supposed to be of 8 feet lift, though in the framing of a final plan they should vary according to considerations not immediately connected with the object of the present report.

The sheet No. 3 exhibits the plan and sections of the lock upon which has been made the estimate of this article of expense. The main walls are built of common range-work masonry, (No. 18;) their facing only is laid with water-line cement. Hewn stone has been used exclusively for the hollow quoins, mitre-sills, abutments, and recesses of gates. The blocks do not exceed 9 cubic feet, (Nos. 27 and 28.) The bottom of the chamber consists chiefly of a reversed arch, built of brick, with water-line cement.

The estimate amounts to $13,069.80. But we must take into consideration that a number of locks will have their foundation upon solid rock, and will therefore require less masonry; and also that owing to the necessary declination, which, in the final plan, the bottom of the canal will receive, the amount of lockage will be less than it is in this general plan. Under these impressions, $12,000 has been deemed a fair average cost of a lock on the whole line of canal.

Respecting the aqueducts, they are to be built of masonry, and their lengths calculated to afford a free passage to the streams at the time of freshets; they are generally to be connected with the sides of the valley by means of embankments carefully made.

We now pass to the description of the canal.

EASTERN SECTION.

[Omitted.]

MIDDLE SECTION.

This section includes the summit-level, and extends from Cumberland (or rather from the western end of the eastern section) to the mouth of Castleman's River, in the Youghiogheny. Its length is seventy miles 1,010 yards; but a lockage of 1,961 feet and a tunnel of four miles 80 yards long, under a ridge of 856 feet elevation, will make this section extraordinarily expensive.

This section will, besides, require the erection of dams across the valleys through which it passes, and more especially in the bed of Will's Creek. This stream, in fact, affords, in summer and fall, a too small supply of water toward its sources to rely altogether upon it; the summit-level must feed, therefore, the upper portions, while frequent dams erected across the valley will make available the water delivered by the stream.

The valleys of Will's Creek and Castleman's River being formed of a succession of flats and bluffs, the canal will often require to be supported by walls whose height should place the work out of reach of the freshets. These freshets rise in Will's Creek from 7 to 10 feet, and from 12 to 16 feet in Castleman's.

In planning this section, care has been taken to avoid, as much as practicable, expensive aqueducts, and none is to be erected over Castleman's River. The canal will follow, constantly, the right side of the valley, whose southern exposure will procure an earlier navigation in spring and later in autumn. Respecting Will's Creek, its valley is so narrow at some places, and the height of freshets so inconsiderable, that four crossings have been made to take advantage of the most favorable ground, and thus lessen the expense. It must be observed that these two streams are not navigable, and will, therefore, require no peculiar work to accommodate their trade and navigation.

The execution of the tunnel will be not only very expensive, but also long and difficult; all the geological appearances lead to the conclusion that the excavation will have to be made through sandstone rock. The estimate has been calculated for three different kinds of ground, hard clay, sandstone, granite, and unstratified limestone. The hypothesis of sandstone being admitted here, the estimate relating to this kind of ground accompanies the present report. (See sheet No. 5.) The tunnel will require to be lined with masonry, experience having shown that this precaution is indispensable. Brick masonry has been adopted in the estimate as the most convenient to fulfill the object. The dimensions of the interior of the tunnel are, 22 feet in width, 7 feet under the water-line and 16½ feet above the same line, which form 23½ feet from the bottom to the top of the arch. The tow-path is 4 feet wide. The shafts destined to facilitate the excavation, and to air the tunnel, are proposed to be sunk 180 yards apart from center to center. Their diameter will be 6 feet within the lining of brick masonry. A gallery, lateral and parallel to the tunnel, corresponds with the shafts. This gallery, or heading, is destined to drain the tunnel during its excavation; its width is 3 feet, and its height 6½ feet; it is lined with brick masonry, and communicates with the tunnel by means of arcades or side-headings, which correspond to the points at which the shafts terminate into the heading. The sheet No. 4, herewith annexed, exhibits all the draughts relating to this tunnel, and to the deep cuts at its ends.

The deep cut at the western end is 1,060 yards long; that at the eastern, 140 yards: each opens into a basin having 880 yards in length and 64 yards in width. The tunnel, the deep cuts, and the basins, form together the summit-level, whose length will be 5 miles 1,280 yards; a lock is located at each end, and where each basin terminates.

Let us now examine the resources upon which we can rely to supply with water this summit-level, and the portions of canal contiguous to it. The stream upon which we have chiefly to depend is Castleman's; it yielded in 1825 and 1826 the following results:

	Cubic ft.
June 21, 1825, at Pleucher's farm, per second	1
July 10, 1825, below Flaugherty's Creek	3
July 12, 1826, at its mouth	46
March 21, 1826, at Pleucher's farm	9
March 27, 1826, below Flaugherty's Creek	715
March 21, 1826, at Forney's mill-dam	536

We have admitted, in the former part of the present report, 18 cubic feet per second as the minimum of water yielded by Castleman's River; and we have also pointed out two reservoirs, one at Pleucher's farm and the other at Forney's mill, containing together 22,000,000 cubic yards. These are the resources afforded by the localities to feed the summit-level and supply its lockage and also portions of canal contiguous to the summit-level.

The reservoirs are to be filled in winter, during the interruption of the navigation—an interruption which, considering the elevation of the summit-level above the ocean, 1,903 (?) feet, cannot be supposed less than four months, viz.: from the 1st of December to the 1st of April. By adopting 98 cubic feet per second as the mean supply afforded in winter by Castleman's River, at Pleucher's farm, we find that in less than seventy-two days both reservoirs would be filled up.

However, to remove any doubt on the subject, we will take an area of thirty-six square miles of ground whose rain-water supplies Castleman's River, and make a computation of what such an area would yield; we will suppose it to be formed of two strips of land, each of eighteen miles long and one mile wide, and stretching along the banks of Casselman's River above Forney's mill.

From observations made from 1817 to 1824, inclusively, by Mr. Lewis Brantz, in the vicinity of Baltimore, we have the following results: In the course of these eight years there fell, on a mean average, yearly, 39.89 inches of rain; in 1822 there fell the smallest quantity, which was 29.20 inches; the greatest quantity fell in 1817—it amounted to 48.55 inches.

Adopting these data for the country round the summit-level, and using only the results of the year 1822, we find that the rain which fell in the three first and three last months of said year amounted to 16.70 inches, and for the six other months to 12½ inches.

	Cubic yards.
These 16.70 inches are equivalent per square-yard surface to	0.463
The 12½ inches are equivalent per square-yard surface to	0.347
The whole, or 29.20 inches, are equivalent per square-yard surface to	0.81

Applying now these last results to the area of thirty-six square miles above mentioned, we find that they will receive at the minimum:

	Cubic yards.
During the fall and winter	51,630,796.80
During the spring and summer	38,695,219.20
The whole year round	90,326,016.00

From which it will be seen, first, that the two-thirds of the first quantity, or 34,420,531$\frac{2}{10}$ cubic yards, would be about one-third more than will be necessary to fill up the reservoirs in four months; second, that 44 cubic feet per second would make up, during six months, the two-thirds of the second quantity, and might, therefore, be deemed the mean discharge per second of Castleman's River during spring and summer, instead of 18 cubic feet, assumed in the present report; third, that this surplus will partly replenish the reservoirs during the time of navigation.

If to these considerations we add that, instead of thirty-six square miles, we might easily have taken double, we may conclude that, the filtrations and evaporations of rain-water being taken into the most liberal account, the portion of Castleman's Valley above Forney's mill will convey to the bed of this river more water than we have admitted; we believe, therefore, that the minimum supply of the summit-level will consist of, first, a reservoir of 22,000,000 cubic yards; second, 18 cubic feet per second of running water. And, since the navigation is supposed to be opened during eight months, the monthly resources will be 2,750,000 cubic yards from the reservoirs, 1,728,000 cubic yards from the river itself; total, 4,478,000 cubic yards per month. Let us see now how the use of this monthly supply will be regulated. Taking into consideration the unavoidable delays at the end of the summit-level, the impediments at the debouches of the tunnel and through the deep cuts, and, finally, the greater resistance the boats will meet through the tunnel, we cannot suppose less than 3 hours and 25 minutes for a boat to pass from one end of the summit-level to the other, which comes to one and two-thirds miles per hour. But the passage is to be effected in fleets or trains, on account of economy both of time and water; and we adopt thirty boats for each train—a number which in the present case seems to us favorable to combine the time of passage with the supply of water during the same time. These thirty boats, moving in train, will meet with more delay than would a single boat, and instead of 3 hours and 25 minutes, as before stated, we assign 4 hours to the train to pass from one end to the other of the summit-level.

We suppose, also, that a fleet of thirty boats, descending the eastern lock of the summit-level, and (through the same lock) passing an ascending fleet of the same number of boats, will effectuate this cross-passage in eight hours, under the plausible supposition that 16 minutes will be required for the cross-passage of a boat ascending and one descending. A similar cross-passage is supposed to take place at the western lock of the summit-level, and at the same time.

Now, a first fleet leaving the eastern lock will arrive four hours afterward at the western lock, and meet there a fleet coming from the west, and ready to proceed eastward. This second fleet will reach in four hours the eastern lock, and find there a third fleet, having ascended the lock during the passage of the first and second fleets. This third fleet will proceed westward, and arrive four hours after at the western lock, where it will find a fourth fleet, having ascended the lock during the passage of the second and third fleets. Lastly, this fourth fleet will move eastward and reach in four hours the eastern lock, meeting there with a fleet from the east, having ascended the eastern lock during the passage of the third and fourth fleets.

The passages of these four fleets, forming together 120 boats, and requiring four hours each, may be considered, as will be seen just now, the maximum of trade which the supply of water can admit. At this rate of 120 boats a day, 3,600 might pass per month, and 28,800 during the eight months of open navigation.

Let us now compute the expanse of water which the lockage of these boats will require. Admitting, as in fact will be the case, that, at each lock, one ascending boat alternates with a descending one, each boat will draw, from the summit-level, but one lockful, viz., half a lockful at each end. However, in order to provide for contingencies and unforeseen cases, we adopt one lockful and a half for the passage of each boat through the summit-level. One lockful and a half containing 623 cubic yards, the 3,600 boats passing during one month will require 2,242,800 cubic yards of water, which, being taken out of the monthly supply, amounting to 4,478,000 cubic yards, will leave 2,235,200 cubic yards. This last quantity is destined to feed the canal itself, exclusive of lockage, on a length of 18 miles and at a rate of 120,000 cubic yards per mile and per month, absorption, filtration, and evaporation being taken into account. These eighteen miles comprehend the summit-level, a portion of six miles in Will's Creek, and a similar of also six miles in Castleman's Valley. The remainder of the canal down Will's Creek will be supplied by this stream, while Castleman's River will feed the remainder of the canal descending its valley.

The estimated cost of the summit-level, just described, is as follows:

The tunnel—	
Shafts	$233,032 95
Heading	383,534 83
Side heading	7,704 27
Tunnel	2,495,242 80
Draining	159,469 30
Total cost of tunnel	3,278,984 15
The eastern basin	26,741 14
The eastern deep-cut	18,733 00
The western deep-cut	141,840 72
The western basin	5,668 00
Total estimate of the summit-level	3,471,967 01

The details relating to the estimate of the tunnel are exhibited in the sheet No. 5, annexed to this report. As to the basins and deep-cuts, their detailed estimates have been carried into those belonging to the eastern and western portions of this middle section. We shall now present successively the description of these portions: the eastern, commencing at the eastern end of the summit-level and terminating below Cumberland; the western, beginning at the western end of the summit-level, and debouching into the Youghiogheny below the mouth of Castleman's River.

EASTERN PORTION.

Subdivision 1.—From the eastern end of the summit-level to the mouth of Little Will's Creek:

Distance, 15 miles 460 yards; descent, 1,016 feet; 127 locks.

The canal follows for 8¼ miles the left side of the valley of Will's Creek; it then crosses the stream to descend for two miles along the right bank; crossing again the creek it remains on the left side as far down as the fourteenth mile; it then crosses a third time, to follow the right side of the valley as far down as opposite the mouth of Little Will's Creek.

The considerable descent in so short a distance, the contracted breadth of the valley, the steepness of its sides, the great quantity of excavation in rocky ground, will concur together to render this subdivision very expensive in proportion to its extent.

The distance between the heads of two consecutive locks will not be less than 180 yards. The first six miles will be fed, as stated before, by the summit-level; the remainder will be supplied by Will's Creek. To that effect dams, erected at suitable places, will afford the means of taking into the canal not only the waters of the creek, but also those of its tributaries.

The estimate of this subdivision amounts to (the eastern basin and deep-cut excluded) $2,300,859.28.

Subdivision 2.—From the mouth of Little Will's Creek to the western end of the eastern section, below Cumberland:

Distance, 13¾ miles; descent, 309 feet; 39 locks. From the summit-level, twenty-nine miles 240 yards; descent, 1,325 feet; 166 locks.

At the commencement of this subdivision the line of canal takes a sudden change of direction from nearly east and west to almost north and south. The valley also changes its character, becoming broader, more level, and less rapid in its descent.

The canal continues for ten and one-half miles on the right bank of the stream, passing alternately along steep and rocky hill-sides and through meadow-land, but even in the latter requiring a large quantity of excavation of rock. It then passes over to the left bank, and continues for more than half a mile on favorable ground, when it enters the defile formed by the breaking of Will's Creek through the mountain of the same name.

The difficulties of this passage are great, and continue for more than a mile. The ground then becomes favorable, permitting the canal to pass at the outskirts of Cumberland, to join with the eastern section.

Provision is made for taking in a supply of water immediately below the junction of Great and Little Will's Creeks, and also at several points below. Adjoining Cumberland, the canal will receive a feeder from the Potomac for a supply below, and more especially to complete what is necessary in relation to the first subdivision of the eastern section.

This feeder is proposed to be made navigable, in order to accommodate the trade of the Potomac above Cumberland. Its length is one mile; its width, at the water-line, 30 feet; its depth, 4 feet. At its point of departure from the Potomac a basin is formed in the bed of the river, by means of a dam erected at the first ledge above.

Cumberland. This basin, comprehending an extent of about eight miles, will afford a constant supply of water, and also accommodate the coal-trade of the Potomac. The levees around the basin, the dam, the guard-lock of the feeder, the feeder and its aqueduct over Will's Creek, are included in the estimate of this subdivision.

A basin is contemplated at Cumberland, and adapted to the probable wants of the place; it will be provided with locks to communicate with the Potomac.

The estimate of this subdivision amounts to $1,555,764.32. The estimate of the eastern portion amounts to $3,856,623.60.

WESTERN PORTION.

Subdivision 1.—From the western end of the summit-level to the mouth of Middle Fork Creek:

Distance, 16½ miles; descent, 216 feet; 27 locks.

This subdivision commences at the western end of the basin formed in the valley of Flaugherty's Creek, and into which is introduced the feeder from the reservoirs in the valley of Casselman's. Having already stated all the details relating to this appendage of the summit-level, we find ourselves dispensed from entering into further explanation upon the subject.

The canal for this subdivision is on the right bank of Casselman's River. On this distance, although no very formidable difficulties are presented, yet the amount of excavation of rock, as also the great quantity of walling, will render the work very expensive. The first six miles are to be fed by the summit-level, as it has been stated; as to the remainder, provision has been made, at several places, for taking from Casselman's River additional supplies.

It is to be observed that this upper subdivision of Casselman's River has a descent less rapid than that of the lower; the reverse takes place in the valley of Will's Creek.

The estimate of this subdivision amounts to (the western basin and deep cut excluded,) $1,240,215.32.

Subdivision 2.—From the mouth of Middle Fork Creek to the mouth of Casselman's River:

Distance, 19 miles 1,030 yards; descent, 420 feet; 53 locks. From the western end of the summit-level, 35 miles 1,250 yards; descent, 636 feet; 80 locks.

This subdivision keeps on the right bank of Casselman's River, as far down as 440 yards below its mouth. The nature of the ground through which it passes resembles that of the subdivision above, except in the vicinity of the Youghiogheny, when it becomes much more favorable, offering more earth and less rock for excavation than above. Occasional resorts to the stream will secure to the canal a competent supply of water. And at the end of this subdivision, two feeders, one from Casselman's River and the other from Laurel Hill Run, are introduced for the supply of the section descending the valley of the Youghiogheny.

According to the documents hereto annexed, the estimate of this subdivision amounts to $1,459,316.93. And the estimate of the western portion amounts to $2,699,532.25.

We close the description of the present middle section by offering the following summary of the main facts relating to it:

	Distances.		Ascent and descent.	Number of locks.	Estimate.
	Miles.	*Yds.*	*Feet.*		
Eastern portion	29	240	1, 325	166	$3, 856, 623 60
Summit-level	5	1, 280			8. 471, 967 01
Western portion	35	1, 250	636	80	2, 699, 532 25
Total	70	1, 010	1, 961	246	10, 028, 122 86

WESTERN SECTION.

This section commences 440 yards below the junction of Casselman's River with the Youghiogheny; it follows the right side of the valley to the Monongahela, and hence to Pittsburg, along the right bank of this stream.

The ground on the left of the Youghiogheny is nearly of the same kind as that on the right; the distance and descent the same for either bank; however, the right bank deserves the preference on account of exposure, and of its receiving the main tributaries of the stream; it will not require, across the Youghiogheny, two aqueducts, which would otherwise become indispensable, should the canal follow the left side of the valley.

This section will be supplied with water by the Youghiogheny and its tributaries; and since the eastern end must rely chiefly upon the Youghiogheny, Casselman's River, and Laurel Hill Run, we will first present the results of the gauging of the streams, made in 1825 and 1826, during the month of July:

	Cubic feet.
Casselman's at its mouth, July 20, 1825, per second	40
Laurel Hill Run at its mouth, July 20, 1825	7
Youghiogheny River, above the mouth of Casselman's, July 21, 1825	70
Cubic feet per second	117
Casselman's at its mouth, July 20, 1826, per second	46
Laurel Hill at its mouth, July 20, 1826, per second	26
Youghiogheny River, above the mouth of Casselman's, July 20, 1826	104
Cubic feet per second	176

These results, though obtained at a time of low-water, yet cannot be deemed as the minima of what these streams can afford; when measured they were not at their lowest stage. Therefore, we assume but 70 cubic feet per second as the minimum of water yielded by these three streams taken together, at the driest epoch of the year.

The Youghiogheny gauged at other points has given, in 1825, the following results:

July 28, at the Ohiopyle Falls, per second, 155 cubic feet reduced to 100 cubic feet.

August 2, at Connellsville, per second, 129 cubic feet reduced to 100 cubic feet.

September 2, at its mouth, per second, 260 cubic feet reduced to 150 cubic feet.

The stream, though very low when measured, was not, however, at its lowest stage: but the season was uncommonly dry, and the above reductions may be considered as minimum.

To these resources of running water we must add the following reservoirs:

	Cubic yards.
Indian Creek	210,370
Mountz's Creek	323,889
Jacob's Creek	356,857
Big Sewickly Creek	1,750,180
Dunbar	214,464
	2,855,760

To which may be added the reservoirs which might be formed in Casselman's River and Laurel Hill Run Valleys.

We must remark that the feeders from all these reservoirs will be very short, their length varying from half a mile to four miles only.

Having pointed out the means upon which we have full reliance to feed this section of canal, we shall show their distribution at the same time as we describe the successive subdivisions of said sections.

Subdivision 1.—From the western end of the middle section to Connellsville:

Distance, twenty-seven and one-half miles; descent, 432 feet; 54 locks.

This subdivision begins about one-quarter of a mile below the mouth of Casselman's River. The bottom of the canal is placed here 4 feet above the level of low-water in Casselman's River, in order to afford the greatest advantage in taking a feeder from this stream, and also in using the most favorable ground below.

In the course of the first three miles the ground becomes gradually more difficult until it assumes the rocky and steep appearance which is so peculiarly the character of the Youghiogheny in so many parts of its upper course. To this difficulty of the ground must be added those arising from the necessity of keeping the canal above the freshets, whose elevation varies from 13 to 16 feet.

The ground continues unfavorable as far down as the old salt-works, seven miles from the beginning of this subdivision, where the line pursues, for a short distance, some favorable ground; but it becomes almost immediately thrown upon a steep hill-side covered with loose rocks, and which continues for three miles further to Ohiopyle Falls.

These falls form one of the most remarkable features of the Youghiogheny, and are formed by the river breaking through the rocky base of the ridge of Laurel Hill. The difficulty it has found in forcing this obstacle is plainly indicated by the sudden bend which the river here makes and the rough appearance of the channel it has carved out. It is most fortunate that the line of canal can, by means of a moderate cut, 283 yards long and 18½ feet deep, avoid pursuing the bank of this rugged channel. This deep cut across the neck of the bend of the river has, besides, the advantage of shortening the line by one mile and a half.

A feeder is proposed to be taken from the river a little above the falls, for which the localities are very favorable; but the line of canal, by pursuing the most advantageous ground, has to descend, within the short distance of one mile, 96 feet; which circumstance will oblige to locate the locks too near to each other for presenting ponds of sufficient extent between them. Several plans suggested themselves to obviate this inconvenience: first, to have the intervening ponds sufficiently wide to admit the easy passage of two boats at once, and to supply these ponds and the locks by means of a waste-way parallel to their course; second, to have lateral reservoirs to receive the contents of adjoining locks, and to transmit it respectively to the second lock below; third, to make the ponds liable to have the level of their waters varied from 2 to 3 feet, and thus making them perform the functions of locks. A close examination, when locating the line, will determine which of these means deserves the preference. The two first will cause a greater consumption of water than usual, but as a feeder is to be immediately introduced above for the purpose of supplying the next level below, this consumption is not, in this case, to be taken into consideration.

Below the Ohiopyle Falls the ground continues difficult for about nine miles to Indian Creek. On this distance the canal is mostly to be carried along a steep bank, in part supported by walls, and excavated through rock. The descent is also rapid, being about 160 feet, and requiring 20 locks. Indian Creek is to be crossed by an aqueduct; it will afford a valuable supply of water, for securing which a feeder and reservoir are proposed.

The ground from Indian Creek to Connellsville, seven miles, is still difficult, but more varied in its character than above; it will necessitate alternately steep hill-side cutting, much of which is rock, and some expensive walling, interspersed with some pieces of moderate cutting.

A basin is proposed at Connellsville, on the level of the canal, for the accommodation of the trade of this place; its communication with the river is established by means of locks.

This subdivision is supplied with water by the Youghiogheny above the mouth of Casselman's River, by Casselman's River and Laurel Hill Run. At the Ohiopyle Falls it receives a new supply from the Youghiogheny; at Indian Creek it will also, when necessary, receive a supply from the reservoir formed above the mouth of this creek. From the detailed estimate, hereto annexed, the estimated cost of this subdivision amounts to $1,515,436.59.

Subdivision 2.—From Connellsville to Sewickly Creek:

Distance, twenty-seven and one-fourth miles; descent, 144 feet; 18 locks. From the beginning of the section, fifty-four and three-fourths miles; descent, 576 feet; 72 locks.

Before arriving at Connellsville the line may be said to have completely passed the range of the western ridges, and the face of the country undergoes an entire change. The banks of the river, however, do not so suddenly lose the character they bear above, but it continues to offer a succession of similar, though gradually decreasing, difficulties for some distance below. This subdivision will, therefore, like the portion above Connellsville, require, for almost its whole distance, steep side-cutting and walling alternately; it will, consequently, be expensive.

Mountz's Creek, one mile, and Jacob's Creek, seventeen miles, below Connellsville, will afford a valuable supply of water for this subdivision; but a resort to the river is still considered necessary, and provision is made to effect this a little below Mountz's Creek.

The two creeks hereabove mentioned are to be crossed by aqueducts, which, owing to the great breadth of the valleys, will require, at their ends, considerable embankments.

The estimated cost of this subdivision amounts to $1,306,425.95.

Subdivision 3.—From Sewickly Creek to the mouth of the Youghiogheny:

Distance, sixteen and a half miles; descent, 8 feet; 1 lock. From the beginning of the section, seventy-one and a quarter miles; descent, 584 feet; 73 locks.

This subdivision offers a larger portion of easy cutting than the preceding, but will still require a large portion of side-cutting and walls to pass round the bluffs. These subdivisions are numerous, and though none individually is of great extent, yet they form together a length of several miles of expensive works.

As McKeesport is at the junction of the Youghiogheny and Monongahela, a basin is proposed there for the accommodation of the trade of the latter stream.

The only lateral supply of water for this subdivision is from the reservoir above the mouth of Sewickly Creek, and it becomes necessary to resort to the Youghiogheny again in order to meet the deficiency which otherwise would be felt on the subdivision to Pittsburgh. To fulfill this object, a dam is proposed across the Youghiogheny at a favorable point three miles above its mouth. This dam will require a considerable height, and therefore locks must adjoin it, that the navigation of the stream should not be injured by the works of the canal, but rather be benefited by them.

The estimate of this subdivision amounts to $741,469.54.

Subdivision 4.—From the mouth of the Youghiogheny to Pittsburgh:

Distance, fourteen miles; descent, 35 feet; 5 locks. From the beginning of the section, eighty-five and one-quarter miles; descent, 619 feet; 78 locks.

This subdivision is generally located through favorable ground; however, some side excavation will still be necessary, and a deep cut near Pittsburgh, of about three miles in length and 15 feet of average depth, is indispensable, to avoid a line yet more difficult and expensive.

This subdivision is almost entirely dependent on the Youghiogheny above McKeesport for its supply of water; the streams crossed by the canal afford so little water during the dry season that no reliance can be placed upon them.

According to the documents hereto annexed the estimate of this subdivision amounts to $606,891.60.

Summary of the western section.

Distance, miles	85¼
Descent, feet	619
Number of locks	78
Estimate	$4,170,223 78

Here ends the description of the several sections of the Chesapeake and Ohio Canal, and whose general summary is as follows:

Sections.	Distance.		Ascent and descent.	Nmber of locks.	Amount of estimate.
	Miles.	*Yds.*	*Feet.*		
Eastern	185	00	578	74	$8,177,081 05
Middle	70	1,010	1,961	246	10,028,122 86
Western	85	440	619	78	4,170,223 78
Total	341	1,450	3,158	398	22,375,427 69

The foregoing description shows that the Chesapeake and Ohio Canal presents nearly all the characteristics which contribute to render a work of this kind very expensive, viz. an extraordinary amount of lockage, a long tunnel, passing under a very elevated ridge; walling unusually frequent along the whole line; extensive portions of deep cutting, excavation of rocky ground and side-cutting, predominating from one end of the canal to the other. The tunnel and lockage alone form together four-elevenths of the whole expense, and if, from the total estimate, we take out the tunnel and reduce the lockage to 1,200 feet, (which may be deemed an unusual amount for such a distance,) the estimate would then amount to $16,000,000 only, notwithstanding the other difficulties to be overcome and the accommodation of trade along the valleys of the Potomac and Youghiogheny.

We will also observe that the middle section alone, whose length is but seventy miles, or one-fifth of the whole length of the line, will cost (according to the estimate) $10,000,000, or the five-elevenths of the whole expense, while the eastern and western sections, whose lengths form together the four-fifths of the whole, will cost but $12,000,000, or the six-elevenths of the whole estimate.

We consider, however, as fortunate that these two expensive articles, extra lockage and tunnel, should be found both located upon a section which, after new investigations and mature reflection, might prove to be advantageously superseded by a railway. Indeed, the inexhaustible mines of coal found in the lower parts of the valleys of Will's Creek and Casselman's River seem to point out to us, as a means to avoid this expensive middle section, the expediency of a railway, with either locomotive-engines or stationary steam-engines, used as lifting-power.

We must also observe that this section will be wanted, but after the completion of the eastern and western sections, which two last being in Washington and Pittsburgh, within seventy miles of land communication, would soon point out, by their results, what should be the most expedient mode of connecting them. Perhaps, then, a smooth road, with an easy graduation, would, at first, be resorted to from the mouth of Casselman's River to Cumberland; or, should a great amount of trade warrant it, a railway might be adopted. In this latter case, which we deem the most probable, the revenue of the eastern and western sections would not only afford the usual interest of the capital employed in their construction, but also have a surplus fund with which a railway might be erected.

Therefore, we are decidedly of opinion that for the present the expense relating to the eastern and western sections ought exclusively to be taken into consideration; that the sum of about $12,000,000, to be expended for their construction, will create the means and afford the resources to procure to the work the mode of completion most adequate to its object.

Our instructions being to plan a canal from tide-water in the Potomac to the head of steamboat navigation in the Ohio River, we had not to take into consideration either railways or any other substitute for the difficult and expensive sections of the canal; therefore no operations in the field, no investigations in the closet, have been made in relation to such an alternative. And, indeed, had even our instructions demanded such inquiries, the want of time and the limited means at our disposal would have prevented us from bestowing upon the subject the full and mature consideration to which it is so deservedly entitled. However, we do not hesitate anticipating that a railway from the mouth of Casselman's River to Cumberland will bear, as to expense and time, a favorable comparison with the middle section above described.

We recommend, therefore, for a canal from tide-water in the Potomac to the head of steamboat navigation in the Ohio the route and plan hereinabove described; and we submit respectfully to consideration the expediency of making the surveys and investigations necessary to ascertain, as accurately as practicable, the comparative merits of a railway and a canal for the section of route from Cumberland to the mouth of Casselman's River.

ADDITIONAL SUBDIVISION OF THE EASTERN SECTION OF THE CHESAPEAKE AND OHIO CANAL FROM THE MOUTH OF SAVAGE RIVER TO CUMBERLAND.

Distance thirty miles 350 yards; descent, 312 feet; 39 locks.

The canal for this subdivision remains on the left bank of the Potomac. This plan was adopted after an attentive consideration of the relative advantages and disadvantages of passing the river several times to follow the best ground. But to do this such frequent crossings would be necessary, and attended with so many inconveniences and risks, that this project was deemed the less expedient.

As the object of this subdivision is to attain the coal-mines near Savage River, it was considered whether this might not be attained by a canal of smaller dimensions and less perfect than the main line below; the result of which was that the dimensions and plan of the original canal were adhered to. For, first, it was found, on applying the calculations to the ground, that a very trifling decrease of expense would be made by decreasing materially the dimensions of the canal; and, second, the unfavorable character of the river to a lock-and-dam navigation, which was thought of as a substitute, rendered this scheme almost as expensive, and much inferior in usefulness to the independent canal.

The subdivision begins by a basin formed in the Potomac by a dam, immediately below the mouth of Savage River. The line immediately enters on a most difficult piece of ground, which continues more than half a mile; another half mile is then favorable, after which it continues difficult for three-fourths of a mile, to Westernport. It then becomes favorable, with the exception of several small portions, to the end of the seventh mile, when the great bend of the river, opposite to Paddy Town, causes the ground to become very rugged and difficult for a space of two miles. Below this, for three miles, the favorable ground is intersected by only small portions of rock side. For the ensuing five miles the approach of Fort Hill to the river presents alternately some easy ground, but a large portion of very difficult nature, requiring much walling and excavation of rock. Below this the ground is favorable for three miles, through Cressap's meadow, when difficulties again occur for two miles. The remaining distance to Cumberland is favorable, with the exception of three portions, which are not of very great extent, but which will require extensive works. An aqueduct over Will's Creek will be necessary.

About eight miles above Cumberland it is proposed to place a dam across the river, and to use its water not only for the supply of the lower part of this subdivision, but also of that below.

BERNARD,
Member of the Board of Internal Improvement.
WM. TELL POUSSIN,
Captain Topographical Engineers, and Assistant to the Board.
W. HOWARD,
Civil Engineer, Assistant to the Board.

ABSTRACT OF ESTIMATE.

1,336,618 cubic yards excavation, (18 to 88 cents per yard)	$339,441 46
562,000 cubic yards embankment, (20 cents per yard)	113,257 60
210,931 cubic yards walling, ($3.50 per yard)	720,655 80
2 aqueducts, (3 arches and 2 arches)	66,277 00
41 locks of 800-foot lift, ($12,000 each)	492,000 00
34 culverts	10,200 00
12 bridges	4,200 00
Puddling	31,722 00
Fencing	16,200 00
2 waste-weirs	1,000 00
Total	1,794,963 86

Or 30⅕ miles, at $59,435 per mile.

Appendix B.

REPORT ON THE SALISBURY SOMERSET COAL BASIN, BY J. P. LESLEY, PROFESSOR OF GEOLOGY, UNIVERSITY OF PENNSYLVANIA.

Somerset County, in southwest Pennsylvania, borders on Maryland.

Salisbury and Berlin are towns in its first sub-coal-basin back of the Alleghany Mountains; Ursina and Confluence are in next sub-basin west of Negro Mountain; Ligonier Valley holds the second bituminous coal-basin, and lies west of Laurel Hill.

Connellsville and Blairsville, west of Chestnut Ridge, mark the east outcrop of the third, fourth, fifth, and sixth bituminous coal-basins, extending unbroken into the State of Ohio.

* * * * * * *

The basin of the upper or Salisbury coals extends about nine miles, from near Meyer's mills, at its north end, to just over the Maryland line.

The lower coal-beds, with which we will have less to do, spread down from the top of the Alleghany Mountains under the whole of Somerset County, excepting only the summit of Negro Mountain and the crest of Laurel Hill.

The upper coal-beds, which give to the Salisbury Basin its exceptional importance, have been entirely swept away from the surface of Somerset County, except in two places: 1st, they remain in the long narrow ridge at Salisbury; 2d, they remain in the central part of the Frostburg or Cumberland Basin. They ramain also in eastern Fayette County, in one little hill-top near Ligonier; and the Pittsburg bed has been left in like manner, on Broad Top, in Huntingdon County, under a few acres at the summit of the highest peak of that mountain. With these few exceptions, this bed has been washed, worn, or eroded from the whole surface of Middle and Western Pennsylvania, east of a line drawn through Connellsville and Blairsville. West of this line, and south of the Kishkaminitas and Ohio Rivers, the upper or Pittsburg coal series of beds have more or less escaped erosion, and are spread through western Fayette and Westmoreland Counties, and are mined everywhere along the rivers which flow with and into the Monongahela. At Ursina and Confluence we have only the lower coals. At Connellsville, Greensburg, and Pittsburg we have the upper coals, as also in the Salisbury Hills; also in the center of the Cumberland, George's Creek, or Frostburg coal-basin. The "Pittsburg Bed," the "Connellsville Bed," the "Irwin Gas-Coal Bed," the "Greensburg Great Bed," the big bed at Latrobe and Saltsburg, are all one and the same coal-bed; the same as the lowest of the three upper Salisbury beds, (about to be described,) the same as the George's Creek bed in the middle of the "Cumberland Basin."

This is the fact of first importance in a report on the Salisbury coal-basin.

The fact of next importance is that the coal-bed above described becomes thin and poor toward Pittsburg and down the Ohio, but grows slowly and steadily in size and quality going east along the Pennsylvania Railroad, southeast along the Baltimore and Pittsburg Railroad, and south up the Monongahela.

At Pittsburg it is about 6 feet thick, and injured by pyrites and slate: at Irwin's and Monongahela City it is 8 and 9 feet thick, and a fine gas-coal; at Connellsville and Latrobe it is 11 and 12 feet thick, a noble bed for cooking-purposes. What it was in the country between Connellsville and Meyer's mills we do not know, but when we next meet a fragment of it at Meyer's mills, in the Salisbury ridge, we find it from 12 to 15 feet thick. And finally, in the Cumberland Basin it is 17 feet thick, and everybody knows its quality there by the annual consumption of from one to two millions of tons in Baltimore, Philadelphia, New York, and Washington, and on coastwise and ocean steamers. This is the bed which furnishes almost all the coke used at Pittsburg and the largest part of the raw coal of the Ohio River trade, and its quality is so superior that it has long monopolized the iron-making market at Saint Louis, Mo. This is the bed which furnishes almost all the coal to the gas-works of the seaboard cities and inland towns; and apropos of this circumstance—

The fact of next importance is that the percentage of gas yielded by the coal of this bed increases westward and decreases eastward. In the Pittsburg region it yields from 35 to 40 per cent. of volatile matter; at Blairsville, Latrobe, Connellsville, and Uniontown its average may be called 30 per cent.; in the Cumberland Basin it is sometimes as low as 17 per cent. Its average in the Salisbury Basin will, therefore, be somewhere above 20 per cent. and below 25 per cent.

(NOTE.—I have no trustworthy analysis of these Salisbury coals. One specimen was said to yield 29 per cent. volatile matter. The Ursina, Confluence, or Turkeyfoot lower coals under-run 20 per cent., and lie farther west.)

As we distinguish such coals as semi-bituminous, coals with only 10 to 12 per cent. as semi-anthracite, and coal with from 9 to 5 per cent. as anthracite, we may say (in the market) that the Salisbury coal (of this bed) belongs with the George's Creek Cumberland semi-bituminous steam-coals, the finest steam-coal, by the by, in the world

It has, however, a little more gas, and belongs properly also to the good coking-coals; with an advantage over the Connellsville part of the bed, not in the excellence of its coke, but in making 200 pounds more of coke from a ton of coal, viz, 10 per cent., or whatever else may be the proved difference between the average percentage of volatile matter in the coals of the two districts.

The next important fact to be noticed is that there are three other coal-beds overlying the Pittsburg-Connellsville bed, two of which are also preserved in the Salisbury Basin.

On Cheat River, in Virginia, the whole system of four beds is as follows:

	Feet.
Waynesburg coal-bed, from	6 to 9
Interval, (shales, sandstones, limestone,) from	183 to 207
Sewickly coal-bed, from	4½ to 6
Interval, (shales, sandstone, limestone,) from	40 to 49
Redstone coal-bed, from	4 to 5
Interval, (shales, sandstone, limestone,) from	18 to 6
Pittsburgh coal-bed, from	7 to 14

At Uniontown and Connellsville there are, in all, six beds, well marked, and separated from each other, thus:

	Feet.
Nameless coal-bed	—
Interval	18
Waynesburg coal-bed	1 to 3
Interval	120
Uniontown coal-bed	2
Interval (great limestone formation)	130
Sewickly coal-bed, interval	5
Redstone coal-bed, very thin, interval	86
Pittsburgh coal-bed	14

In our Salisbury coal-basin we have as the highest rock on the hill-tops, the equivalent of the Waynesburg sandstone in the form of a massive conglomerate sandstone called (after its Kentucky name) the anvil-rock—black slate representing the Waynesburg coal-bed.

	Feet.
The upper limestone, black slate, and a little coal	20
Uniontown coal-bed, (coal and slate)	5
The lower limestone	1
Sewickly coal, (upper Berlin, coal and slate)	15
Interval	55
Redstone coal, (double bed)	10
Interval	30
Pittsburg coal, (lower Berlin)	11

Such was the section I made at Myer's mills, in September, 1857. In 1870 I got numerous sections along the southern or Salisbury portion of the basin, which show the usual variations both in the size of the coal-beds and in the intervals separating them, but prove the only fact of importance to us, that the Pittsburg bed maintains its predominant quantity and quality the entire length of the basin. They prove also the Sewickly bed is everywhere large, but not reliable in quality, being very slaty. They prove also that the redstone bed is persistent, but not an unusually large bed. They reveal, moreover, a new and important fact, that there is a valuable coal-bed underlying the Pittsburg coal-bed.

The section of the southern half of the Salisbury basin (upper) coal-measures may, therefore, be thus stated:

	Feet.
The great limestone Sewickly coal bed, (slaty)	10
Interval, (soft shales)	44
Redstone coal-bed	6
Interval, (shales)	10
Pittsburg coal-bed, (with parting 2 feet)	18
Interval containing two small coal-beds	64
Salisbury coal-bed, over	4
Thence down to the level of Casselman River	55

(Opened recently on the Jonas Beechy tract, 15 feet above river, 5½ feet of pure coal.

Although the Salisbury basin is only nine or ten miles long, and one or two miles wide, and cut by numerous short ravines, which make the outcrop of these beds follow zigzag courses around the hill-sides, it will be seen at once, from the above sections, what an enormous quantity of coal has been left in the ridge, and how perfectly accessible it is. I shall give quantities presently.

There lie beneath the river-bed, and conformable to the upper coal-measures just described, the following beds of the lower coal-measures. These have been struck in an oil-well boring as follows in depths from mouth of well:

	Feet.
Elk Lick coal, (called 4 feet thick,) at	96
Upper Freeport coal, (called 10 feet thick,) at	132
Lower Freeport (?) coal, (called 8 feet,) at	252
Black slate and coal, (mixed, 2 feet,) at	300
Johnstown ore-bed, at about	340
Streaks of coal, at about	440
Conglomerate, (forming crest of Alleghany Mountains)	500
And continuing more or less to	640
Red shale of XI, hence down to bottom of well	690

These coal-beds of the lower system spread through the hills east of Casselman's River, and form the mineral riches of all the Berlin, Salisbury, Ursina, and Johnstown country; but they are hardly worthy of entering into our present discussion of the upper coal-beds of the Pittsburg (Salisbury) series, in the Salisbury Basin ridge.

The area occupied by the Pittsburg (Connellsville or Westmoreland) bed is eight and a half miles long; its greatest width is three miles, and the average width opposite Salisbury, and south of Tubmill Run, one mile.

QUANTITY OF PITTSBURG BED-COAL.

The sum total of 5,000 acres of coal-bed is got by deducting about 1,000 acres for loss by valley erosion, and indefinite southwest limit, from 5,955 acres of calculated total coal-bed area between Meyer's mills and the south end of the Salisbury Basin.

The whole area is subdivided naturally into four portions, thus:

		Per foot.
A	2,000 acres, which at 1,000 tons	2,000,000 tons.
B	2,200 acres, which at 1,000 tons	2,200,000 tons.
C	915 acres, which at 1,000 tons	915,000 tons.
D	840 acres, which at 1,000 tons	840,000 tons.
	5,955 acres, which at 1,000 tons	5,955,000 tons.
	Say 5,000	5,000,000 tons.
	Allowing only 10 feet depth to the bed we get	50,000,000 tons.

NOTE.—The above estimate of 1,000 tons to the acre, for each foot thickness of bed, allows for pillars, slack and waste of all kinds, and represents the amount of coal placed in the cars outside.

The actual geological quantity of coal in this Salisbury (Somerset County) outlier of the great Pittsburg bed, must be nearly one hundred millions of tons.

QUANTITY OF REDSTONE-BED COAL.

The area of this bed is about one-half that of the great bed below it, and its average thickness is not so well known. I do not think it prudent to estimate for all its detached areas, ten in number, more than 15,000,000 tons, possibly gross contents 24,000,000 tons.

QUANTITY OF SEWICKLY-BED COAL.

Area about one-tenth of the Pittsburg bed; total of coal of all qualities, 5,000,000 tons. The above estimates are *in minimo.*

QUANTITY OF SALISBURY COAL.

The recent opening of this bed, 5½ feet thick, at an elevation a few yards above the river-level, near the south end of the basin, is a matter of great importance. The coal shown to me in Philadelphia is of superb quality, although somewhat too prismatic to bear long transport. It appears to be as pure as the best George's Creek (Cumberland) coal, and must make first quality of coke. (See analysis at end of this report.) It outcrops all along the river-face and on both sides of Tubmill Run; and its total area must be at least one-half greater than that of the Pittsburgh bed, but I have reason to believe its thickness to be less at the north end than at the south end of the basin. (On Elk Lick Creek is a 4-foot bed of very good coal, but belonging to a lower geological position.)

The Salisbury coal-bed, if even 5 feet thick under the south end of the basin, will contain 25,000,000 tons, the most, if not all, of which lies above water-level. It is then proper to add to the above quantities a total available sum in this Salisbury bed of at least 20,000,000 tons.

QUANTITY OF COAL BENEATH WATER-LEVEL.

Future mining operations in the beds of the lower coal-measures will reveal their condition, thickness, and quantity. They underlie the whole area of, say, 9,000 acres, more or less, which is in question. It is perfectly safe to give two beds yielding 5 feet each, *i. e.*, to say 120,000,000 tons, or on a practical estimate, 90,000,000 tons.

As these lower beds can only be reached by shafts, and as they spread throughout Somerset County, and the upper beds are above water-level and monopolized by a few properties between Meyer's Mills and the Maryland line, it seems hardly worth while to introduce this secondary element into my estimate of the value of the Salisbury Basin, which is in itself, and entirely apart from the existence of these lower coal-beds, so extraordinarily valuable.

NOTE.—In any other coal-region of the world the existence of beds nearly horizontal, and to be reached by shafts less than 300 feet in depth, (see oil-well boring,) would of itself give great value to the overlying properties. My report on the Ursina lands shows that one bed struck by such a shaft is the fine 6-foot coal mined on the north fork of Casselman's River, on the west side of the Somerset Basin. Its analysis is a good deal like that of the Cumberland coal. This 6-foot bed is the great bed of Casselman's River, between Meyer's Mills, Confluence, and Ursina, and it is increasing in thickness eastward, so that the report of its being 10 feet thick under Salisbury (see oil-well boring) may very well be a true one.

I first became acquainted with the isolated and exceptional character of this bed in 1840, during my survey of Somerset, Fayette, and Cambria Counties, in company with James F. Hodge, and as assistant of the State geologist, in whose fifth annual report my sketch of the geology of the Salisbury Basin is embodied, but without details. My knowledge of its peculiarities was much enlarged in subsequent years, and impressed me always more and more. I have frequently urged its claim to special attention, but until the completion of the Connellsville and Cumberland Railroad connection no steps for its development could be profitably undertaken. This connection being now made nothing can prevent this Salisbury Basin from becoming a second, though somewhat smaller, Cumberland Basin, and that without any rival but the Cumberland Basin.

(No. 1.)—For the little hill-top patch of Pittsburgh bed left standing in the Ligonier Valley is entirely out of the way of all trade, and too minute in itself to be of any account; and the Broad Top coals are those of the lower coal-system, small beds and subdivided, hence coming to market in a soft and dirty condition.

The Salisbury upper (Pittsburgh) coals, if coked, can go down to Pittsburgh in competition with the Connellsville upper (Pittsburgh) coal, coked; but the Connellsville coal, raw, is too bituminous to come eastward to Baltimore and Philadelphia in competition with the Salisbury and Cumberland coals, raw. These, then, compete with each other, but without competition from any other quarter whatever, forming virtually two competing but allied monopolies of the best steam-coal known.

To feel the full force of this remark it must be kept in mind that what is called *par excellence* "Cumberland coal" comes from the "Big bed," (George's Creek bed, Pittsburg bed,) in the center of the Cumberland Basin, and what will soon be equally famous as "Salisbury coal" will come from the same Big bed, Pittsburgh bed, in the central ridge of the First Somerset or Salisbury Basin.

In considering the commercial value of these coal-beds in comparison with each other and the transportation distances by the many existing and proposed new routes to the eastern markets, it is to be borne in mind that the two coals, the Salisbury and Cumberland, come from one and the same (Pittsburgh, Connellsville, Salisbury, George's Creek) upper coal series Great coal-basin, and are of equal purity, and the beds of equal size or rather of greater size at Salisbury.

It is especially to be remembered that the Irwin coal (Westmoreland) is only to be used for gas-making purposes, and can only be brought eastward for those purposes; for coking purposes it must go to Pittsburgh and down the Ohio. Whereas the Salisbury coal will rival the Cumberland coal on a footing of equality, as the best steam-coal known, and have nothing but the Cumberland coal to compete with; for the Broad Top and Alleghany Mountain steam-coals all come from the smaller, more slaty, and softer beds of the lower coal system, and therefore always must be of inferior value in the market to the Cumberland and Salisbury coals; while on the other hand the Salisbury coal will coke admirably also, and command an equal standing in the Pittsburgh and down-Ohio-River markets.

Observing, finally, that the noble coals of Jefferson and West Clearfield, about to enter the seaboard markets, on the completion of the Low Grade Railroad, must travel three hundred and twenty miles to reach Philadelphia, and then come into the seaboard market in competition with the Irwin gas-coal kinds, (transported three hundred and thirty-two miles,) to which they really belong, (although the beds are the upper beds of the lower coal system,) and cannot, therefore, compete well with steam-coals.

Considering all these points, I think I have justified the very exceptionable value which I have for many years past attached to the Salisbury coal-basin.

NOTE.—Analysis referred to:

Analysis of the five-foot Salisbury bed, mentioned in this report, made by Booth & Garrett

Gas	16.02	Volatile matter	25.75
Tarry matter and water	9.73		
Fixed carbon	68.40	Coke	74.25
Ash	5.85		
			100.00

NOTE.—Assuming the specific gravity of the gas to be 0.45 compared with air as unity, the amount of gas yielded by one pound of coal will be 4.64 cubic feet. This analysis shows, first, the resemblance of this coal to the Cumberland; second, the great amount of coke it will produce even after a certain loss of fixed carbon.

Appendix C.

LETTER OF MR. B. H. LATROBE.

BALTIMORE, *March* 2, 1874.

DEAR SIR: Upon my return home yesterday I received your letter of the 26th February, asking for information in regard to the cost of the Sand-Patch tunnel upon the line of the Pittsburg and Connellsville Railroad.

The work on this tunnel, of 4,800 feet in length, was commenced and carried on for a couple of years or more prior to my connection with the road, and I am not now able to say from sources within my reach what it cost during that time. It was resumed in 1865, after a suspension of about eight years, and within the next two years the sum of $31,549 was expended in removing 7,620 cubic yards, at an average cost of $4.14 per cubic yard. This work was done by the day under the superintendence of an agent of the company, an experienced and trustworthy person, formerly and since a contractor upon the line. It gives, therefore, a pretty good criterion of actual cost without profit, although if done by contract the net cost might have been somewhat less, the desire to make a profit affording, even to an honest man, an additional incentive to economy.

There were 350 feet linear of heading and 500 feet of bottoming in the 7,620 cubic yards, the former constituting about one-third and the latter two-thirds of the whole sectional area of the tunnel, which was 16 feet wide by 18¼ feet high, with semicircular roof where masonry was not required, with 2 to 3 feet additional width and height where lining was needed. The lining was of stone, as no good brick-clay was found in the neighborhood, and very good sandstone abounded in the large bowlders of the conglomerate rocks which were found strewn over the surface in the vicinity.

The employment of this stone permitted the arch to be reduced from 18 inches (had it been of brick) to 12 inches in thickness, which sufficed for so moderate a span, the space over the arch not requiring more than 2 or 3 feet of packing, except at certain points where the rock had fallen more from overhead. The strata were inclined crosswise to the line of the tunnel, the dip being 40° or 50°, and the strike being nearly parallel to the axis of the tunnel, the grade ascending 1 in 100 from east to west, and the rock consisting of the old red sandstone underlying the coal-measures. A long canal-tunnel would cut across the stratification and encounter the lower coal-measures after passing through the old red and the mountain limestone and the millstone grit. After the final resumption of the work on the Sand-Patch tunnel in 1868, it was let to contractors, at the following prices:

Heading, what remained, (748 cubic yards,) nearly all being removed under previous contract	$7 per cubic yard.
Bottoming, what remained, (27,725 cubic yards)	$2.95 per cubic yard.
Stone packing over arch, (5,085 cubic yards)	$2.25 per cubic yard.
Side walls, stone masonry, (374 perches of 25 cubic feet)	$12.00
Arch, stone masonry, (1,899 perches of 25 cubic feet)	13.25

The railroad company furnished cement and sand, costing about $1 per perch, to be added to these prices.

The tunnel and approach-cuts, which were long, were made passable by trains in March, 1871; and since, some extension of the arching has been made, so that now about half the whole length, I think, is lined.

Since writing the above I have found some papers which give the prices of the first contract, made in 1853, viz: Heading, $5.25; bottom, $2; packing over arch, $2; shafts, (four in number, and 88, 120, 142, and 178 feet deep, respectively,) $6 per cubic yard. These were sunk before I took charge of the work. The first contractors abandoned the work, the prices being inadequate even at that day of lower prices of everything. The last contractors made a small profit by close management. The whole tunnel and approaches have cost about $420,000.

I should think it very unsafe to assume the preceding prices in estimating the cost of a long canal-tunnel, which might readily be 100 per cent. higher, and, for the shafts, three or four times as high.

The Sand-Patch tunnel was remarkably free from trouble with water, the rock of alternately hard and soft ledges, unfit for masonry, and much of it decomposing when exposed to the atmosphere.

I am, dear sir, respectfully yours,

BENJ. H. LATROBE.

Col. W. E. MERRILL,
United States Engineer Office, Cincinnati, Ohio.

INCLINED PLANES.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, May 8, 1874.

GENERAL: In my report on the extension of the Chesapeake and Ohio Canal, dated March 20, 1874, and printed as Executive Document No. 208, House of Representatives, Forty-third Congress, first session, I stated, under the heading "Inclined Planes," that Colonel Sedgwick was preparing a special paper on the method of canal navigation by the use of inclined planes, which I intended to forward with the request that it might subsequently be attached to my report. I have just received the paper in question, and I herewith forward it, with the request that it may also be transmitted to Congress for publication. The subject discussed is one whose details are not widely known, and the information which the report contains will be quite useful to all engineers who have to discuss the problem of canal navigation in mountainous districts.

Respectfully, your obedient servant,

WM. E. MERRILL,
Major Engineers.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers.

Supplemental report of Mr. Thomas S. Sedgwick, Assistant Engineer.

WASHINGTON, D. C., *March* 30, 1874.

COLONEL: In relation to the extension of the Chesapeake and Ohio Canal from Cumberland, Md., to Pittsburg, on the Ohio, I have the honor to make a supplemental report on the study of "inclined planes" as a means of raising and lowering boats from one level of a canal to another, instead of the canal lift-locks.

The use of such planes is not new, although they are somewhat of a novelty. They have been in use on the Duke of Bridgewater's Canal in England, and planes carrying caissons full of water in which the boats were floated have been used on the Monkland Canal, near Glasgow, Scotland; but the most noted and, doubtless, the most successful application and use of inclined planes is a matter of national pride to the United States, in the example of their efficiency and economy in cost, and saving of time in transportation, as used on the line of the Morris Canal, in New Jersey.

The Morris Canal extends across the northern portion of New Jersey, from Easton, Pa., on the Delaware River, to tide-water at Newark, on the Bay of Newark, a distance of one hundred and one miles. The total rise and fall on the canal is stated at 1,557 feet, of which 223 feet is overcome by locks of various lifts, and 1,334 feet by inclined planes, averaging 58 feet lift each, of which one, near the western terminus of the canal, has a height of 100 feet.

These planes were, when first constructed, operated in connection with an ordinary lift-lock placed at the head of the plane, connected with the upper level or pool, into the bottom of which lock the track (an ordinary railway-track) of the plane was laid, and led down the plane to the lower pool. The boats were carried up or down the plane on a wheeled carriage running on a railway-track operated by an endless chain passing around large horizontal pulleys, (fixed at the head and foot of the plane,) and attached to a large winding drum operated by a turbine motor, and the usual gearing and machinery for transmitting such power. The turbine with its machinery is located in a house on one side of the plane at about the middle of its length, and is operated by the head of water taken from the upper pool. The boats were taken into the locks at the head of the planes in the usual manner, and as the prism of lift-water was discharged the boat settled down into the carriage and was let down the plane to the lower pool, where the boat, following the inclined plane to a depth greater than the draught of the boat, floated and was detached, passing on its way. Boats moving in the contrary direction were drawn over the carriages as they stood in the lower pools at the foot of the planes and made fast thereto, and the machinery being put in motion, the carriage rising along the planes, the boats settled down upon them and were carried up to the head of the planes and into the locks, which were then closed, the prism of lift-water let in, and the boats were raised to the upper pool and passed on their way.

The locks at the heads of the planes have been taken away, and the railways of the planes are carried over into and down to the bottom of the upper pools, where the boats are received and discharged from the carriages in the same manner as at the foot of the planes in the lower pools. This arrangement of the two planes is called a "*summit-plane*," and this is the kind of plane I have considered in connection with the extension of the Chesapeake and Ohio Canal, with special reference to their application on the mountain section of the Savage River route, between the mouth of Savage River and Salisbury, on the Castleman River, and at one or two places farther west on the route where their usefulness is apparent.

The loaded boats of the Morris Canal, together with the carriage, weigh about 110 tons. Observations made on the operating of a plane at Newark, rising one foot in ten, and having a lift of 70 feet, showed that boats were readily and efficiently passed from one pool to the other, over a horizontal distance of about 1,000 feet, in four
2 8/10 minutes, equal to a rate of ~~twenty-eight~~ miles per hour.

DESCRIPTION AND ESTIMATE OF COST.

The accompanying drawings, showing a profile and plan of a single-track plane, and a plan of a double-track plane, illustrate the arrangements and dimensions of a summit-plane of 64 feet lift, rising one foot in 10 feet. H is the upper and L the lower pool or level of the canal, connected by the inclined plane. The summit of the plane at S is from 1¼ to 2 feet higher than the surface of the upper pool, and the second branch of the plane descends to the bottom of the upper pool at the rate of 1 foot in 10 feet, and the foot of each plane is continued beyond the ordinary depth of the canal to gain depth enough to allow the carriage to pass under the boat as it floats, as shown t A. The additional depth shown in this plan is about 6 feet, requiring a total depth of 12 feet. P and P are the horizontal pulleys around which the traction cable passes connecting the carriage with the winding-drum D. They are *firmly* fixed to masses of masonry. The turbine motor, connecting with the winding drum by suitable gearing, is placed in a suitable house at the foot of the plane to utilize the available hydraulic head between the pools.

The carriage is formed of two parallel trusses, each resting on two trucks of two iron wheels, each flanged like ordinary railroad-car wheels. The trusses are connected by bearing joists or floor-beams on which the boats rest while being moved up or down the plane. The trusses are carried by bolsters resting on axle-pivots at O O in such manner that the trucks may, in moving over the crest of the plane, adjust themselves to the plane of the track by turning about the axle-pivots. The track upon which the carriage runs consists of the ordinary T railroad rail laid on longitudinal stringers, which are placed on a foundation wall of masonry, put deep enough in the ground to be undisturbed by the freezing of the ground in winter. The traction cable C is supported on grooved carrying-wheels placed at proper intervals, and iron rollers are used to carry the cable over the crest of the plane. The carrying-wheels placed between the drum and the horizontal pulleys move horizontally on their axles, adapting themselves to the horizontal motion of that portion of the cable as it winds off or on the drum. The planes are increased in length in proportion to the depth reached in each pool, and a portion of level track is laid in each pool for the carriage to rest on when receiving or discharging a boat, the pulleys being placed at the ends of the level portion of track.

The total height of the main plaine from the bottom of the lower pool to its crest or summit is 77.5 feet, and the height of the plane in the upper pool is 13.5 feet. The horizontal lengths of the planes are therefore 775 feet and 135 feet, and their slope lengths are 778.86 and 135.67 feet, which, together with two level portions of 100 feet each, makes the track needed 1,114.5 feet long. [Fifteen feet are taken from each end, eaving 1,085 feet of track.]

The length of cable used is twice the lengths between the pulleys, measured on the planes, the circumference of one pulley, and the distance passed over by the carriage in going from one pool to the other, say 980 feet, a total length of 3,235 feet. The ends of the cable are separately fixed to the drum, and a length of cable equal to the distance passed over by the carriage is always wound on the drum. In the double-track plane the length of cable is twice the distance between the pulleys by the planes, once and a half the circumference of a pulley, the distance between the tracks, the distance passed over by the carriage, and twice the distance from the drum to the pulleys in the upper pool, in all 4,140 feet.

The gauge of the track is 18 feet, and the slopes of the canal-prism, if carried to a depth of 12 feet, will not provide room enough for the single-track plane, and the necessary widening and the excavation of the prism between the foot of each plane, and the surface of the pool is considered in the cost of the single-track plane; and in the cost of the double-track plane the expense of widening to a width of 75 feet for a distance of 300 feet in each pool is included.

The expense of deepening the canal to a depth of 12 feet for a distance of 100 feet in each pool is also included in the cost of the single-track plane.

COST OF SINGLE-TRACK PLANE.

Deepening pools, 2,150 cubic yards, at 40 cents	$860	00
Grading surface of plane, say 3,000 cubic yards, at 30 cents	900	00
Trenches for masonry of track, 500 cubic yards, at 30 cents	150	00
Foundation walls, 350 cubic yards, at $8 per yard	2,800	00
Track-stringers, 15,000 feet, board-measure, at $35 per thousand	525	00
Fastening stringers to wall, 450 pounds bolts, at 6 cents	27	00
Track-rails, 80 pounds per pard, 25.8 tons, at $90 per ton	2,322	00
Joint splices, 70, at $1 each	70	00
Track-spikes, 400 pounds, at 5 cents	20	00
Laying track, say	100	00
Carrying-wheels and rollers, 8,500 pounds, at 5 cents	425	00
Grooved-pulleys, 5,000 pounds, at 4½ cents	225	00
Traction-cable, 3,235 feet steel-wire cable, 2½ diameter, $1.65	5,337	75
Turbine diameter, (in place)	1,000	00
Gearing 20 tons cast iron, at $100 per ton	2,000	00
Drum and fixtures, 2 tons, at $100 per ton	200	00
Flume and penstock, complete, with feed-gate	5,640	00
Fixing grooved pulley, (masonry and iron)	450	00
House for machinery	1,500	00
Boat-carriage, carefully figured	2,500	00
Sum of items	27,051	75
Contingencies, 10 per cent	2,705	17
Cost of plane	29,756	92

COST OF DOUBLE-TRACK PLANE.

Cost of single-track plane	$27,052	00
To which add the following quantities:		
Additional widening, 3,000 cubic yards, at 40 cents	1,200	00
Trenches for foundation, 500 cubic yards, at 30 cents	150	00
Foundations, track-masonry, 350 cubic yards, at $8	2,800	00
Track-stringers, 1,500 feet, board-measure, at $35 per thousand	525	00
Stringer-fastenings, 450 pounds bolts, at 6 cents	27	00
Track-rails, 25.8 tons, at $90	2,322	00
Joint splices, 70, at $1	70	00
Track-spikes, 400 pounds, at 5 cents	20	00
Laying track	100	00
Grooved pulley, (large,) 5 tons, at $100 per ton	500	00
Carrying wheels and rollers, 5,000, at 4½ cents	225	00
Traction-cable, 910 feet, at $1.65	1,501	50
Fixing pulley	250	00

Boat-carriage, as figured	$2,500 00
Movable carrying-wheels, 2,500 pounds, at 6 cents	150 00
Sum of items	39,392 50
Contingencies, 10 per cent	3,939 25
Cost of double-track plane	43,331 75

ECONOMY OF COST AS SUBSTITUTE FOR LOCKS.

In a mountainous country, where a considerable elevation is to be overcome in comparatively short distances, and where the ordinary lift-locks must be placed in flights, so called, that is, adjacent to each other, or be placed so close together as to seriously retard navigation as to time, the pools being so short that the average usual speed cannot be acquired between the locks, (and the time lost in locking and attendant delays consume a great part of the time on the section where the locks are so close together,) or where, to avoid such loss of time, the lifts of the locks must be made so great that the requisite supply of feed-water cannot be had, (such locks being also very expensive in their construction,) the locks in either case being a principal item of the cost of the canal, as well as a continual source of delay in transportation, if there should be but one lock for each mile, the cost of locks would be but some $16,000 per mile; but if the levels of the canal, as in some well-known cases, were ten or twelve miles long, then the cost of the locks would be but some $1,500, or even only $1,000 per mile for the ordinary lifts of eight feet; on the contrary, if the canal is to be carried into a mountainous region, where the slope of the valleys must be followed at a rate of 50 or 60 feet rise per mile, requiring 6 or 8 locks per mile, their cost becomes the principal item of expense, and may reach as much as $130,000 per mile.

Considering the section of the Chesapeake and Ohio Canal between Cumberland and Connellsville, via the Savage River route, as presented in my report of January 30, 1874, we find the cost of locks between Cumberland and the mouth of Savage River equal to 28 per cent. of the whole cost of the canal—$21,000 per mile—the locks occurring at intervals of three-quarters of a mile. At the mouth of Savage River the ascent of the mountain begins, and between that point and the summit, a distance of sixteen miles, there are 140 locks, aggregating more than 75 per cent. of the estimated cost of the canal for that section.

If, to avoid this high ratio of cost of lift-locks on the line of canal, we consider the substitution therefor of the single-track inclined-plane, as described above, we find that one plane overcomes the lift of eight locks of 8 feet each. [This lift of the plane was assumed with special regard to this section of the canal, as, in my judgment, they can be economically placed at average intervals of about one mile.] Eighteen planes would be required to overcome the elevation of the Savage River section, where there are 140 locks, and two planes for the section between the western end of the Summit Tunnel and the mouth of Piney Run, where there are 16 locks in 6 miles. On these two sections the slopes of the hill-sides are favorably conditioned for supporting the levels of the canal for such use of the planes.

The 156 locks, estimated on this section of the canal at $16,500, (with 10 per cent. contingencies,) would cost $2,574,000, while, on the contrary, the 20 planes would cost but $595,138.40, a difference of $1,978,861.60 in favor of the planes, equal to a saving of 76.88 per cent. of the cost of the locks, and reducing the cost of this section of the canal by 58.58 per cent. Comparing the cost of the plane with the cost of the eight locks it would take the place of, there is a difference of $102,243.08 in favor of the cost of the plane, overcoming the same height of lift by the plane as by the eight locks, at 22.5 per cent. of the cost of the locks.

There are no natural indications that planes could be used between Cumberland and the mouth of Savage River, and the cost of supporting the levels of the canal on the hill-sides might be a greater increase (in the cost of high embankments, or the crossings of lateral ravines or valleys, and high aqueducts) than would be saved by the planes of less lift than described above.

There are, however, two places on the line of the canal west of Meyer's Dale City where planes could be advantageously used. Referring to the report of the Board of Internal Improvement, (1st subdivision, western section.) there is a reference to the Ohio Pyle Falls, where the fall is 96 feet in the distance of one mile. The cost of a plane of this height would be, in addition to the cost of the 64 feet high plane, the cost of 321.6 of track and traction-cable and their accessories, amounting to $3,068.45, including 10 per cent. contingencies, making the total cost of the plane $32,825.45; while, on the other hand, twelve locks of 8 feet lift each would cost $198,000, a difference of $165,174.55 in favor of the plane. The other place I refer to as indicating the substitution of a plane for locks is at the mouth of Castleman River. The use of a plane at this point would save $102,243, as found above. These items of difference in cost aggregate $2,246,279.15, which is applicable to the reduction of the cost of the canal as estimated in my former report, reducing the cost from $19,937,285 to $17,691,006, a reduction of 11.25 per cent.; a sum that, rated as an invested capital, at 6 per cent. per annum, is equal to a saving of $134,776.75 in annual expense of maintaining the canal.

This character of inclined plane could also be applied on the Wills Creek section of the Wills Creek route under very similar conditions, as will be seen by reference to the report of the Board of Internal Improvements, "eastern portion" of middle division, where the intervals between the locks are given as 180 yards, equal to 540 feet, and the average of six locks per mile obtains between Cumberland and the summit of the mountain.

EXPENDITURE OF WATER IN OPERATING THE TURBINE MOTORS.

In determining the work to be done in moving boats over the plane, the weight of the boat is taken at 30 tons, the weight of the cargo at 120 tons, and the carriage at 35 tons, making an aggregate load of 185 tons, or 414,400 pounds. Resolving this weight with reference to the plane rising 1 on 10, we have for the pressure perpendicular to the plane 412,343.4 pounds, and for the weight acting downward, parallel to the plane, 41,234.34 pounds. This weight, together with the friction of the load, is to be overcome in moving the load up the plane. Taking the friction at eight pounds per ton of the weight normal to the plane, we have for the rolling friction 1,472.66 pounds, which gives the force to be applied in moving the load 42,707 pounds—moment pounds—parallel to the plane.

To raise the load one foot high, the travel along the plane will be 10.05 feet; and the corresponding foot-pounds will be 429,205.35. To move the boat at a rate of 2½ miles per hour gives a rate of 3.66 feet per second horizontal, or 3.685 feet along the plane, and the corresponding foot-pounds are 157,375.44 pounds. As 550 foot-pounds are rated as one horse-power, we require 286.20 horse-power to move the load 3.685 feet in one second, or to raise it one foot high in one second. Adding five per cent. for friction of machinery, we get quite nearly 300 horse-power as the measure of work per second required for the turbine motor.

To determine the diameter of the turbine to do this work, and the quantity of water expended per second, in cubic feet, with a height of head of 64 feet, we have, by the formulas and proportions deduced from the Lowell hydraulic experiments, (by Mr. James B. Francis, C. E.,) for the diameter of the turbine 3.71 feet, and the water discharge 56.26 cubic feet per second. To move the carriage over the distance from the average place at the foot of the main plane until the rear wheels are over the crest of the planes toward the upper pool, whence the force of gravity will take it to the foot of that plane, a distance of 825 feet, will require 3.75 minutes' time and expend 12,433 cubic feet of water. [These formulas consider the useful effect of the turbine as 0.75 of that due to the hydraulic head.]

As turbines are so arranged that the expenditure of water is in proportion to the work done, we have an expenditure of 4,368 cubic feet of water to draw an empty boat, 65 tons, (with carriage,) up the plane, and, to move the same loads from the upper pool over the crest of the plane a distance of 200 feet, we have an expenditure of 3,014 cubic feet for a loaded boat, and 1,059 cubic feet for the empty boat. These quantities need not be necessarily fully expended, as a part of the work is done in moving the load over whatever distance the rear trucks of the carriage may be from the foot of the plane when the movement begins, and in carrying the rear trucks of the carriage over the crest of the plane; times in which the full power of the turbine is not required.

The movement of boats up or down the slopes of a canal, whether operated by planes or by locks, are somewhat analogous. When the canal is operated by locks, each loaded boat passing up the canal draws from the upper pool one lockful of water, plus the boat's displacement, and an empty boat one lockful, plus its displacement; and in passing down the canal each boat draws off from the upper pool a lockful of water less its displacement, when the locks are found empty; but if the locks are found full, the down-going boats will force the quantity of their displacement out of the locks into the upper pool. [A lockful of water is considered as part of the lower pool.] In the case of the locks under consideration, the prism of lift contains 12,000 cubic feet, and a loaded boat displaces its weight of 150 tons, 5,391 cubic feet, and an empty boat its weight of 30 tons, 1,078 cubic feet, of water; and in making a comparison of the expenditure of water in the two systems of working the canal, the displacement of the downward-going boats will be credited for the case of finding full locks.

To make the conditions of comparison equable in the two systems, we will first consider the expenditure of water by four boats (two loaded and two empty) going up, and two loaded and two empty going down, giving the benefit of full locks to one loaded and one empty boat going down

Direction and condition of boats.	Lock system.	Planesystem.	Difference in favor of plane.
	Cubic feet.	*Cubic feet.*	*Cubic feet.*
Two loaded boats going up	34, 782	24, 866	9, 916
Two empty boats going up	26, 156	8, 736	17, 420
Loaded boat down, (lock empty)	6, 609	3, 014	3, 595
Empty boat down, (lock empty)	10, 922	1, 059	9, 863
Loaded boat down, (lock full)	5, 391	3, 014	2, 377
Empty boat down, (lock full)	1, 078	1, 059	19
Total for eight boats	72, 000	41, 748	....
Giving an average for each boat	9, 000	5, 218½	3, 781½

Showing a difference of 42 per cent. in favor of the inclined-plane system.

If, for a second comparison, we consider only loaded boats going in each direction, taking for example two boats each way, and giving one boat the benefit of finding a full lock going down, we find as follows:

Direction and condition of boats.	Lock expends.	Plane expends.	In favor of plane.
	Cubic feet.	*Cubic feet.*	*Cubic feet.*
Two loaded boats going up	34, 782	24, 866	9, 916
One loaded boat down, (lock empty)	6, 609	3, 014	3, 595
One loaded boat down, (lock full)	5, 391	3, 014	2, 377
Totals for four boats	36, 000	30, 894	....
Giving an average for each boat	9, 000	7, 724	1, 276

Showing a difference of 14 per cent. in favor of the inclined-plane system.

If we apply this method of comparison of the expenditure of water to the summit-level of the canal, we shall find that, when we consider the system of inclined planes, each loaded boat passing the summit draws off from the summit-level 15,447 cubic feet of water, and each empty boat 5,427 cubic feet of water, in the operation of the two summit-level planes, an average of 10,437 cubic feet to each boat; and if we take the case of the locks, each boat passing the summit, loaded or empty, draws off either 24,000 cubic feet or 12,000 cubic feet, as the lock by which the boat leaves the summit-level is found empty or full, an average of 18,000 cubic feet for each boat, a saving in the expenditure of water of 42 per cent. in favor of inclined planes. If we consider only loaded boats passing the summit we find for the inclined-plane system an expenditure of 15,447 cubic feet of water for each boat, and for the lock-system an average (again) of 18,000 cubic feet, or 14 per cent. in favor of the inclined plane. This is the best *practical* comparison that can be made in favor of the lock-system, and shows that the expenditure of water by this system of inclined planes is 86 per cent. of the expenditure by locks.

The most favorable assumption that can be made in favor of locks is that which presumes that the boats alternate in direction regularly and continuously day by day, and month by month, throughout the season, in which case each boat would expend but one lockful of water in passing the summit-level; but this recurrence of boats is not presumable, and any derangement of this order for one day is not compensated by a similar disorder of recurrence on following days, and consequently presuming that two boats may go in one direction to one boat in the contrary direction, one and one-half lockfuls of water are estimated to be expended by each boat passing the summit-level. This irregularity of directions of boats increases the expenditure of water at the summit by 50 per cent. in the lock-system, but with the system of inclined planes such irregularity in direction makes no change in the quantity of water expended at the summit, thus avoiding any doubt as to the supply required for a given number of boats, as each boat requires a given expenditure in passing the summit-level. In the case of locks, if twenty or thirty boats should pass the summit in the same direction and following each other they would each expend two lockfuls of water, or more than double the quantity that would be expended by the same number of boats passing in the same order by the system of planes.

There is, however, a general condition of commercial transportation, which considered as a basis of comparison between these systems of operating the canal with especial regard to the expenditure of water in its daily operations, gives great weight to the system of inclined planes.

The movement of freights between the East and the West, by the lines of transportation already established, shows that the freights eastward are greatly in excess of the freights westward, in the proportion of about 6 to 1. This indicates that about six loaded boats would go eastward to one loaded westward, that five-sixths of the boats going westward would be empty, and all going eastward would be loaded, consequently we may presume that of twelve boats passing the summit-level of the canal seven may be considered as loaded and five may be considered as empty. By the system of locks each boat passing the summit-level will have an average expenditure of 18,000 cubic feet of water, or 216,000 cubic feet for the twelve boats, but by the system of inclined planes the seven loaded boats will expend 108,129 cubic feet and the five empty boats will expend 27,125 cubic feet of water, a total of 135,254 cubic feet, an average of 11,271 cubic feet for each boat, or only 62 per cent. of the expenditure by locks. Upon this hypothesis of the movement of boats loaded and empty, the quantity of water required for operating the inclined planes may be determined definitely for any given number of boats, and generally the quantity of supply of feed-water at the summit may be determined upon the basis of tonnage per annum; 100 boats would carry (58 being loaded and 42 empty) 6,960 tons, and expend 1,127,117 cubic feet of water, about 162 cubic feet per ton, varying as the tonnage; whereas, on the contrary, by the lock-system the 100 boats passing the summit would expend equal quantities of water whether loaded or empty.

It may be further remarked that by the system of planes the loss by leakage at the locks would be entirely obviated at the summit-level, an insignificant quantity probably, but yet worthy of being noted.

Referring again to the comparison of quantities of water expended at planes and at locks in the eastern slope of the canal, and applying the hypothesis of non-balance of freights eastward and westward, we find that six loaded boats passing eastward, and one loaded and five empty ones passing westward, will expend 52,357 cubic feet of water, and by the same movement of boats through a lock by the favorable condition of three eastward boats, finding full locks, there will be expended 73,357 cubic feet of water, nearly one-half more than the quantity expended by the inclined plane. This feature of the comparison, together with the absence of leakage at the summit-locks, shows that, in the system of inclined planes, the storage water in the summit-level is under better control in the matter of its distribution down the slope of the canal, saving in the last case 33 per cent. of the water expended by the system of locks, under the same condition of tonnage. This feature gives great weight to the system of inclined planes.

The local conditions in regard to these comparisons are, on the Savage River section of the canal, especially favorable to the system of inclined planes.

EFFECT ON THE TONNAGE CAPACITY OF THE CANAL.

It was shown in my former report that the tonnage capacity of the canal is dependent on the facility for passing boats at the restricted points as at the locks, and was equal, under ordinary circumstances, to about eight boats per hour, and 192 per day. Upon the basis of movements of freights eastward and westward, given above, seven-twelfths of these—12 boats—are loaded, aggregating a tonnage of 4,032,000 tonnage for a season of 300 days. In the case of the inclined planes, boats can be passed up (and down) over a distance of 950 feet in 4.4 minutes, allowing for time to get into the carriage, say ten boats per hour, increasing the capacity 25 per cent. With regard to the convenience of passing boats at a plane, it may be readily shown that they can be passed over the plane in one-half of the time, or in any other ratio, by the same expenditure of water, by increasing the power of the turbine motor.

If double-track planes were applied to the canal at the increased cost of 50 per cent., the capacity is to some extent unlimited, and ten boats could be passed in each direction in each hour, doubling the capacity last stated, which would give 480 boats per day, and 144,000 boats, 17,280,000 tons, per annum of a season of 300 days.

ECONOMY OF TIME IN TRANSPORTATION.

To determine the time of transit over a canal operated by locks, the time taken up in slowing up the boat to enter the lock, and the time taken up in getting under way again at the usual speed, must be taken into the account as the means of determining the time lost by retardation of speed, as well as the time required in locking through. A like amount of retardation takes place in passing a plane, as the boat must come very nearly to a dead stop in entering the carriage, but by good management the boat may be made to leave the carriage with the communicated velocity acquired in passing over the plane—2¼ miles per hour.

[This is the practice on the Morris Canal.]

To determine the time consumed at locks in retardation and locking, we may take the operations on the completed canal as a basis. Under the most favorable conditions of the lock being open to an approaching boat, the tow-line is cast off at the distance of 350 feet from the lock, and the boat comes to a stop when in the lock, and we will assume that an equal distance is required to get under way again at the usual speed.

The lock for this purpose is taken to be 120 feet long; and the distance occupied in slowing up, locking, and getting under way again is therefore 820 feet at each lock. The usual speed acquired over the canal between locks is two miles per hour, rarely faster. Loaded boats make the trip from Cumberland to Georgetown, a distance of 184.5 miles, in 4½ days, passing through 74 locks, making an average speed of 1.7 miles per hour.

The total distances taken to slow up, lock, and get under way are, for 74 locks, 60,680 feet, leaving 913,480 feet, over which the speed of two miles per hour is made, requiring 86½ hours of time, and the time remaining of 4½ days, 21½ hours, is taken up at the locks in retardation and locking, equal to $17\frac{4}{10}$ minutes at each lock, in passing over 820 feet of distance. To render this case somewhat more favorable, we will assume that but 15 minutes' time are taken up in slowing up, locking, and getting under way.

In applying these measures of time to the portion of the canal between Cumberland and Connellsville, via the Savage River route, we will consider it in characteristic section. Connellsville to mouth of Piney Run, 68 miles, with 134 locks; Piney Run to mouth of Savage River, twenty-eight miles, with 156 locks; and Savage River to Cumberland, thirty-one miles, with 42 locks.

In passing over the first section of 68 miles, a boat will take up 33.5 hours in passing 134 locks and 109,880 feet, leaving 249,160 feet to be passed over at the rate of two miles per hour, requiring 23.6 hours, a total of 57.1 hours for this section. On the middle section, deducting the tunnel summit-level of 5 miles length, which will be passed in 2.5 hours, 39 hours will be taken to pass 156 locks and 127.920 feet of distance, equal to 24.23 miles, 1.23 miles more than the distance to be passed over on this section, exclusive of the tunnel. The reason for this result is that the distances between the locks average about 660 feet, 40 feet less than is assumed to be taken up in getting under way, and slowing up to enter the next lock, and the boat does not get the speed of two miles per hour, as assumed, but in the half distance between locks will acquire a speed of 1.89 miles per hour. [As we have assumed nearly 2½ minutes less time at locks than was found by the basis of times on the portion of canal in operation, we may disregard this saving of a fraction of a minute.] The whole time on this section is 41.5 hours. The time occupied in passing over the section from the mouth of Savage River to Cumberland, we have 10.5 hours to 42 locks, and 34,440 feet of distance and 12.24 hours to pass over the remaining 129,240 feet or 24.48 miles, making for this section 22.74 hours, and for the whole distance between Cumberland and Connellsville, 121.34 hours. a rate of 1.05 miles per hour. If the 17.4 minutes found to be occupied at each lock had been used in these calculations the time would have been found to have been 13.28 hours more, or 134.62 hours.

BY SYSTEM OF INCLINED PLANES.

The time required for the passage of boats along the canal where inclined planes are used is to be determined in the same manner as for the system of locks. Equal times and distances are taken up in slowing up to enter the carriage, as in the case of locks, but no time is lost in retardation in getting under way again. If a boat, moving at the rate of two miles per hour, comes to a stop in 350 feet when the propelling power is stopped, the average rate of speed has been one mile per hour for the 350 feet of distance and the time 4 minutes, quite nearly. In the calculations for determining the expenditure of water in passing the plane, the rate of two and one-half miles per hour was assumed, and to pass from the upper to the lower pool, or *vice versa*, a distance of, say, 990 feet, the time will be 4½ minutes, making 8½ minutes for the time taken at each plane to pass over a distance of 1,340 feet.

Considering first the section between the mouth of Piney Run and the mouth of Savage River, a distance of twenty-eight miles, with 20 planes, we have for the time occupied at planes, 2.83 hours and 26,800 feet of distance, and the remaining distance 22.92 miles is passed over in 11.46 hours, and the section is passed in 14.3 hours, (a saving in time of 27.2 hours on this section,) with a rate of two miles per hour, quite nearly, the section being passed as if it were *one continuous unobstructed level.*

The saving of time at the other points named would be, at the mouth of Castleman River, difference between 2 hours occupied at the eight locks in going over 6,520 feet and 8½ minutes and 29.4 minutes (37.9 minutes) to pass the same distance by the plane, a saving of 1.37 hours.

At the Ohio Pyle Falls, a plane of 96 feet lift would give a distance of 1,310 feet to be passed in 6 minutes, and 1,660 feet in 10 minutes; 12 locks would require 3 hours of time to 9,840 feet of distance, while in passing this distance with the plane but 56¼ minutes would be taken, saving here 2.06 hours; and the whole time that would be saved between Connellsville and Cumberland is 30 hours and 38 minutes, (equal to a shortening of the canal by 61.26 miles,) making the time from Connellsville to Cumberland 94 hours, only four days, and the average speed 1.35 miles per hour. If the time of passing locks as found by the operations of the canal in use, had been used, the saving in time would have been almost 4½ days.

It is quite probable that planes could be introduced at other places on the canal, but the surveys are not made in such detail as to determine this.

From the above discussion of planes and locks it is apparent that if planes of higher lift could be used, the economy of time and cost would be greater yet; and that were the canal operated to its full capacity with planes, the planes could be double-tracked at an increased cost not exceeding 46 per cent. of the cost of the single-track planes, which would establish a double line of boats moving in opposite directions as fast as two miles per hour over the mountain section; nor would the double-track planes expend as much water in operating the turbines as would the single-track planes, because the load to be moved up or down the plane would be counterbalanced by 35 tons, or 60 tons, or 185 tons; and in all cases 33 per cent. of a saving in work would take place; and in the case of the movement of two boats at the same time, one or the other of the boats might be said to have been moved without any expenditure of water; and for the case of six loaded boats down, or eastward, and one loaded boat and five empty ones westward, on the Savage River section, if the boats could be moved over the planes in pairs, the expenditure of water would be for the five empty boats up, and the one loaded one, 36.204 cubic feet, or an average of 2,901 cubic feet for each boat as compared with 4,363 cubic feet for each boat as found for the single-track plane, a saving, again, of nearly one-half of the quantity estimated for the operation of single-track planes.

In the operations of the double-track plane, when two boats were to be moved at the same time, double work would have to be done in moving the boats over the length of the upper plane, and for this purpose a turbine of double the power figured for the single-track plane would be required with double the expenditure of water for that time, and this double expenditure is considered in the calculation of the last average quantity of 2,901 cubic feet. Fixed caissons carrying water in which the boats may be floated while passing over the plane, have been used, as noted in the beginning of this report. Such an arrangement would add the weight of caisson to the load to be moved and also the weight of water required to float the boat, which would be an additional load of about 115 tons, and would require an additional expenditure of water in the same ratio for like movements of boats. In the case of a double-track plane with caissons, the same increase in expenditure of water would be necessitated; but in the case under discussion, that system of arrangement *must* be established that expends the least quantity of water.

In whatever manner the comparison may be made between the lock-system and the inclined-plane system, either of single locks and single-track planes, or of double locks and double-track planes, the economy in construction and in the expenditure of water is pre-eminently in favor of the inclined planes.

Stationary steam-engines could be substituted for the turbine motors, but their cost would be $15,000 additional at each plane. They would be more liable to accident, and require skilled superintendence and the constant expense of fuel, while, on the contrary, they would avoid the expenditure of water needed to operate the turbines.

EFFECT ON COST OF TRANSPORTATION.

Taking the operations of the completed canal between Cumberland and Georgetown as a basis of cost, a careful analysis of the cost of transporting coal shows a cost of 0.4 cent per ton per mile, exclusive of tolls, when the rate of transportation is 1.7 miles per hour, or at the rate of 0.68 cent per hour of time, and consequently a saving of 30¼ hours' time works a saving of 20.8 cents per ton between Connellsville and Cumberland, an equated saving of fifty-two miles in distance by the system of inclined planes, in comparison with the system of lift-locks as herein compared.

Very respectfully,

THOMAS S. SEDGWICK.

Maj. WM. E. MERRILL,
U. S. Engineers, Brevet Colonel, U. S. A.

N 9.

SURVEY OF THE YOUGHIOGHENY RIVER, PENNSYLVANIA.

UNITED STATES ENGINEER OFFICE,
Cincinnati, Ohio, August 14, 1874.

GENERAL: I have the honor to forward herewith Lieutenant Mahan's report on the survey of the Youghiogheny River, as ordered by the act of March 3, 1873.

The cause of the delay in getting this report before Congress is explained in the report itself.

Having no special instructions as to the limits of the survey I directed Lieutenant Mahan to commence at West Newton and work down stream to the mouth of the river. I selected West Newton as the starting point because I understood that the wishes of those at whose instance this survey was ordered were to have an extension of the Monongahela slack-water system up the Youghiogheny; and therefore I thought it best to limit the survey to a length of river that could be examined thoroughly, and not to go above a point that could be reached by three dams of 10 feet lift each, believing that there would be ample time to continue the survey after these dams were built. I had no instructions to make this survey a part of the examination for the extension of the Chesapeake and Ohio Canal route, and therefore treated the question as a purely local one.

After the estimate for an improvement by permanent dams had been made, I directed Lieutenant Mahan to make another estimate for the construction of movable dams, on the model of that across the Seine at Port-à-l'Anglais. I did not expect that this system could be advantageously applied to the Youghiogheny, but I thought that it would be a valuable study for similar work on the Ohio.

The mouth of the Youghiogheny is in the second pool of the Monongahela, and, therefore, boats descending the former stream must pass two locks before reaching free navigation in the Ohio. For this reason, and for its increased cost, I would not recommend an improvement on the Youghiogheny by movable dams.

The most serious question in improving this river comes from the scantiness of its water-supply in summer. On this account the estimate for lock-foundations is particularly large in order to reduce leakage to the minimum.

The estimated cost of slack-water to West Newton, by three locks and dams of 10 feet lift each, is $688,023.21. This is a larger estimate than is usual for such locks and dams, but it will be seen on examination that the increase of cost arises from the defective character of the foundations.

Accompanying this report are fourteen sheets of maps, giving the plat of the part of river surveyed on the scale of 1 inch to 200 feet, its longitudinal profile, and various cross-sections. There is also a sheet on which is shown, on a small scale, the kind of movable dam on which the estimate was based. The movable parts are Chanoine wickets, and the arrangement is similar to that adopted at Port-à-l'Anglais on the Seine just above Paris.

Respectfully, your obedient servant,

WM. E. MERRILL,
Major of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

Report of Lieut. F. A. Mahan, Corps of Engineers.

UNITED STATES ENGINEER OFFICE,
Cincinnati, July 28, 1874.

SIR: I have the honor to submit the following report of the survey of the Youghiogheny River from West Newton to McKeesport:

Having been ordered for temporary duty to the Atlantic coast just two weeks after my return to this office, and not having had with me any maps or other data from which a report could be prepared, I have been compelled to wait until the present time before completing it, as upon my return I found that certain additions had to be made to the maps, the data for which were to be found only in my own note-book.

The act of Congress approved March 3, 1873, reads as follows, in so far as it concerns this work:

"Sec. 2. That the Secretary of War is hereby directed to cause examinations or surveys, or both, to be made at the following points, namely: * * *

"The Youghiogheny River, Pennsylvania."

* * * * * * *

Your orders, given to me verbally, were that the survey should extend from McKeesport, at the mouth of the river, to West Newton, about twenty miles up; consequently nothing was done outside of these limits.

The Youghiogheny rises near the boundary-line of the States of Maryland and West Virginia. Its course is about due north as far as Confluence, where its direction changes to west-northwest, preserving this general direction unchanged until it joins the Monongahela at McKeesport. A few small, unimportant streams empty into it above Confluence, at which point it is joined by its two most prominent tributaries, Castleman's River and Laurel Hill Creek. Below Confluence three other streams flow into it, but they are also very small. The Youghiogheny runs very nearly parallel with the Monongahela; just below its head-waters it is crossed by the Baltimore and Ohio Railroad. At Confluence the Pittsburgh, Washington and Baltimore Railroad comes on its right bank, which it follows thence to McKeesport. The Pittsburgh, Wheeling and Baltimore Railroad is a branch of the Baltimore and Ohio Railroad, which it joins at Cumberland, Md.

There are no towns of any importance between McKeesport and West Newton. The distances of the principal villages from Pittsburgh are as follows:

	Miles.
McKeesport, on the right bank	15.7
Boston, on the left bank	19.4
Osceola, on the right bank	21.7
Alpsville, on the right bank	22.5
Shauer's, on the right bank	26.2
Buena Vista, on the left bank	27.7
Armstrong's, on the right bank	27.7
Moore's, on the right bank	28.8
West Newton, on the right bank	34.5

In times of very high-water steamboats could go up to West Newton, and perhaps even farther, were it not for the bridge that here crosses the river, and is about 10 feet above high-water.

I could not find any data for determining an average high-water at West Newton, as no one seemed to take any particular notice of the river. The highest water there known occurred on the 7th of February, 1868, and stood at 23.94 feet above low-water. This rise was caused by an ice-gorge in the river below.

The river in times past has been slack-watered, but I have so far been unable to obtain any satisfactory information about its history or its work. I could only find traces of two locks and dams, one about a mile below Osceola, the other at Buena Vista, but they had long been lying in ruins, the dams completely broken through, and the locks almost totally destroyed. Nothing of them is now standing save small portions of the chamber-walls. So far as I could learn from conversation with persons living in the neighborhood of the river, the great cause of failure was in the dams having been built too high. What this height was exactly I could not learn, but the lift from pool to pool was about 13 feet.

The survey was made in August, September, and October of 1873. The force at first consisted of Mr. Hoag, myself, and five men, the number of whom was afterward increased to seven. Considerable delay was caused by the difficulty of obtaining suitable transportation for the party and instruments, but work was finally begun on August 11 and continued until November 1.

The party was divided into two sections. The first, under Mr. Hoag, took in the topographical and hydrographical parts, while the second, under my own supervision, attended to the leveling. The topography was conducted by the ordinary methods of courses and bearings. A system of diagonal time-soundings was made from West Newton to McKeesport, and at all marked shoals lines of triangulated soundings, 200 feet apart, were run perpendicularly to the shore.

The leveling was conducted with the special object of determining the difference of level between the water-surface at West Newton and the water-surface in the second pool of the Monongahela slack-water system. Eleven bench-marks in all were established. They are all cut on rocks and in the form of a Greek cross, the center of the cross being the point at which the rod should be held. The following description of the bench-marks may be useful for future reference:

No. 1. On top of a sandstone guard-post, situated at the intersection of the curbs on the northeast corner of Main street and the street fronting the river, in West Newton. The block is 18 inches high, horizontal section 14 by 8 inches, top face 12 by 6 inches, B. M. on top face. This bench being the starting-point of levels, its reference was arbitrarily assumed at 250.0. All references in this survey are in feet.

No. 2. A cross cut on the sixteenth stone from the water-front, seventh course from the top, north side of the east abutment of the West Newton bridge. Reference 248,157.

No. 3. A cross cut on the eighth stone from the water-front, twelfth course from the top, north side of the east abutment of the West Newton bridge. Reference 240,209.

No. 4. A cross cut, with a figure 4 alongside, on a large flat stone, about two miles below West Newton, on right bank. The stone is a little to the left of a line through the chimney of a paper-mill at West Newton, tangent to the left bank of the river. The stone is 20 by 9.5 feet, cross is 0.22 foot square, figure 4 is 0.26 foot long. Reference 224,245.

No. 5. A cross cut on the northwest corner of the top foundation-course of the east abutment of the railroad-bridge crossing Sewickly Creek, near its mouth, may be known by a large V cut near the northeast angle of the cross. Reference 225,030.

No. 6. A cross cut on a large stone directly across the river from Suter's Pier, at Sutersville. Reference 221,196. This B. M. is very badly cut, on account of the nature of the stone, which, being slaty in its character, would not work well under the chisel.

No. 7. A cross cut on a large piece of conglomerate, irregular in shape and reddish in color. It is situated on the left bank of the river, about 800 yards below the old slack-water dam at Buena Vista. Reference 214,908.

No. 8. A double cross (‡) cut on a large out-cropping bowlder on the left bank of the river, a little below Robbins's Run. The point of rest for the rod is at the cross nearest the channel. Reference 206,453.

No. 9. A cross cut near the top of a large stone on the left bank of the river. Above the cross is an arc of nine small holes drilled into the stone, which is situated midway between the Alps House (a large hotel at Alpsville, on the right bank) and the Coultersville Baptist church, a very prominent frame building, with long windows, standing near the southwest end of Alpsville. Reference 211,291.

No. 10. A cross, surmounted by a letter X, on a flat stone lying on the right bank, between the coal-tipples of N. J. Bigley and Brown & Cochran. Reference 200,863.

No. 11. No description will be here given, as it has since been destroyed.

No. 12. A cross cut on a large stone on the left bank of the river, almost in the prolongation of Sixth street, McKeesport. Reference 206,309.

The above description will, I think, be sufficient to enable any one to determine the location of any of the benches without difficulty.

In determining the difference of level between the water-surface at West Newton and at McKeesport, the rule was adopted to repeat on the morning of each day the work done on the preceding afternoon. After reaching the end of the work, it was gone over twice from end to end, continuously, for the purpose of checking. On account of my having been laid up sick, the final leveling was done by Mr. Hoag, and our work agreed within five-hundredths of a foot. The difference of level found was 25.427 feet. From this subtract 1.1 feet, the depth of water at the bridge, and we obtain 24.3 feet as the difference of level between the Monongahela pool and the bottom of the river at West Newton. A depth of 6 feet at West Newton would give the water-surface 30.3 feet above the Monongahela pool. This can be divided into three pools, requiring a lift of 10 feet to pass from pool to pool. The remaining 0.3 could be removed by dredging.

Owing to the low stage of water, the bottom of the river was distinctly visible for almost the entire distance from West Newton to Alpsville. The surface of the bottom is formed of gravel, except in a bend just above Sutersville and below the old dams, in which localities the surface-stratum was found to be of sand. As we were unprovided with the necessary boring-tools, we were unable to determine what formation underlay the bottom. This is a question that must be carefully investigated before any final locations for the locks and dams can be decided on.

The discharge of the river was determined by Mr. Hoag at Rattle's Ripple. He made use of surface-floats over a course of 40 feet in length, the average depth of the section being one foot. The amount of discharge he found to be 183 cubic feet per second, which will give 10,980 per minute, or 658,800 per hour. Now, the size of lock proposed for use in this work is that of the large locks on the Monongahela. The chambers of these locks measure 250 feet in length by 56 in breadth. These dimensions, with a lift of 10 feet, give 140,000 feet as the amount of water required for one lockage. About twenty minutes is needed for a boat to pass one of these locks, or three boats can pass in an hour, requiring 420,000 cubic feet of water in the same time, and leaving a surplus of 238,800, or 1$\frac{5}{7}$ of a prism of lift. Now, when the river was gauged, although it was very low, it was not at its lowest stage, and, judging by information furnished me by the inhabitants in conversation, I am inclined to think that the supply in a dry season must be so scant that it would hardly be sufficient. On this point, however, it was impossible to obtain reliable data, as the people living near the river do not seem to study its movements with any care. Granting, however, that this supply (183 cubic feet per second) can be kept up, it will be easily seen that the water must be carefully husbanded, and that a dam of the very best design to prevent leakage will be required, and that the foundation for the lock must be made very tight, in order that the water may not escape through it.

To form three pools three dams will be required. As the exact location of each dam has not been determined on, I have only been able to *assume* a length for each one. Taking that point on each pool where there will be 6 feet of water, and measuring the distance from the top of the bank on one side to the top of the bank on the other, we find the sum of the three distances to be 1,850 feet, which, deducting 85 feet for width of lock, gives the total length of the three dams of 1,595 feet, or an average length of 532 feet for each dam.

These dams I propose to construct as follows: 1st. To build strong timber cribs, about 6 feet in height and 50 feet in width, and place them in line across the stream. 2d. To drive a row of heavy square piles along the down-stream side of the cribs, for the purpose of keeping them in position, the tops of the piles to be flush with the upper surface of the cribs. 3d. To drive on the up-stream side of these cribs two rows of 8-inch sheeting-piles in juxtaposition, the rows to break joints. These piles to be driven so that their tops shall be flush with the top surfaces of the foundation-cribs, the up-stream row of sheeting-piles to support the lower ends of the timbers composing the apron of the dam. 4th. To build a strong crib on top of these foundation-cribs, and make it a continuous structure from one end of the dam to the other. This super-crib to be 10 feet in height, the down-stream side being built in three steps of 3½ feet each, the up-stream side being an apron formed of heavy timbers, wrought to true faces, and laid as close together as possible. The apron to have a slope of 1 perpendicular to 2.5 base. 5th. The crest of the dam will be formed by a timber 12 by 18, thoroughly bolted and fastened to the crib-work. 6th. To fill in all the crib-work with riprap. 7th. To cover the entire up-stream side of the dam from the top of the apron down with gravel, the top surface of which is to have a slope of 1 perpendicular to 6 base.

ESTIMATE FOR ONE DAM 532 FEET IN LENGTH.

14,167 linear feet of piles, 12½ cents per foot	$1,770 87
90,720 feet (board-measure) sheet-piles, at 35 cents per M	3,175 20
848,400 feet (board-measure) timber in crib-work, at $35 per M	29,694 00
127,000 feet (board-measure) timber in apron, at $35 per M	4,445 00
532 piles, driving, at $2.50 each	1,330 00
1,064 sheeting-piles, driving, at $2.50 each	2,660 00
11,000 cubic yards riprap, at $1.25 per yard	13,750 00
10,588 cubic yards gravel, at 40 cents per yard	4,235 20
Total cost of dam	61,060 27

MASONRY ABUTMENT.

At the end of the dam opposite the lock will be an abutment of stone, extending 30 feet above and below the dam, with wing-walls 40 feet in length. The abutment is to be 5 feet thick at the top and 10.5 feet thick at the bottom, the side next the bank to be vertical, the height 22 feet. It is to rest on a foundation of piles in four equidistant rows parallel to the face of the abutment, the piles in each row to be 5 feet apart. A capping-piece 12 by 12 inches will be laid on each row of piles, and the grillage thus formed covered by a platform of 5-inch plank laid crosswise upon it. The top of the platform to be laid on a level with the bottom of the foundation-crib of the dam. On this platform will be built the abutment.

ESTIMATE FOR ABUTMENT.

3,040 linear feet of piles, at 12½ cents per foot	$380 00
9,120 feet (board-measure) grillage, at $35 per M	319 20
9,975 feet (board-measure) platform, at $35 per M	349 13
438 cubic yards quarry-face masonry, at $9.60	4,204 80
636 cubic yards rubble masonry, at $7.20	4,579 20
5,000 cubic yards riprap for protecting banks, at $1.25	6,250 00
152 piles, driving, at $2.50 each	380 00
Laying grillage	33 00
Laying platform	70 00
Total for abutment	16,565 33

The foundation adopted for the lock is similar to that of the lock recently built at Henry, on the Illinois River, the bed in each case being permeable soil. In this case, however, additional precautions have been taken to guard against leakage on account of the scantiness of the water-supply.

Before going farther it may be well to give a brief description of the Henry lock.

This lock is built entirely in the bed of the river, the center line at the head being 350 feet from the low-water line, and at the foot 150 feet. The earth where the foundition is placed was first removed to a depth of 6 feet. Three thousand two hundred bearing piles 12 inches in diameter were driven so as to have five rows under the entire length of each wall, the piles in each row being 3 feet apart, the remainder of the piles being driven over the chamber space in seven parallel rows, the piles in these rows being also 3 feet apart. Under the head-bay the longitudinal rows are doubled, being fifteen in number. Longitudinal foundation timbers 12 inches square were then placed on these piles and securely bolted to them. Cross-timbers 12 inches square were then laid on these and securely bolted to them, forming a grillage. The spaces between the timbers, and to a depth of 3 inches below, were filled with concrete, thus making a depth of concrete of 27 inches. All the foundation was then covered with 2½-inch plank. Six rows of sheeting-piles were driven across the foundation, the piles being from 4 to 6 feet in length.

The additions I propose to make to the above are, to increase the depth of concrete to 36 inches; to put in ten rows of sheeting piles instead of six; to put at the head of the lock two rows of sheeting piles, 8 feet apart, instead of one, and to fill in the intermediate space with 6 feet depth of concrete; all the sheeting-piles to be 10 feet long instead of 4 to 6 feet.

As the lock here proposed is smaller than the Henry lock, the chamber of which is 250 feet by 75, the number of piles will be reduced from 3,200 to 2,309.

ESTIMATE FOR FOUNDATION OF LOCK 250 FEET LONG BY 56 FEET WIDE.

46,180 linear feet of piles, at 12¼ cents per foot	$5,772 50
173,440 feet (board-measure) sheeting-piles, at $35 per M	6,070 40
42,000 feet (board-measure) sheeting-piles, at $35 per M	1,470 00
135,000 feet (board-measure) lower-flooring course, at $35 per M	4,375 00
51,050 feet (board-measure) upper-flooring course, at $35 per M	1,786 75
8,400 feet (board-measure) binding-strips at $35 per M	294 00
1,100 cubic yards of concrete, at $6 per yard	6,600 00
7,000 cubic yards of earth excavation, at $1 per yard	7,000 00
2,309 piles, driving, at $2.50 each	5,772 50
1,050 sheet piles, driving, at $2.50 each	2,625 00
Laying grillage	550 00
Laying flooring	1,000 00
Total cost of foundation	43,316 15

The lock is to be of stone. Dimensions of chamber, 250 by 56 feet; lift, 10 feet; walls, 22.5 feet high, 10 feet thick at top, 13.5 feet thick at bottom; 350 feet total length.

ESTIMATE FOR LOCK.

2,000 cubic yards cut-stone masonry, at $14.40 per yard	$28,800 00
1,200 cubic yards quarry-face masonry, at $9.60 per yard	11,520 00
3,513 cubic yards rubble masonry, at $7.20 per yard	25,293 60
4,000 cubic yards earth filling, at 50 cents per yard	2,000 00
1 lift-wall, 167 cubic yards quarry-face masonry, at $9.60 per yard	1,603 20
4 gates, complete, at $4,000 each	16,000 00
Total cost of lock superstructure	85,216 80

SUMMARY.

Cost of dam	61,060 27
Cost of abutment	16,565 33
Cost of lock foundation	43,316 15
Cost of lock superstructure	85,216 80
Cost of one lock and dam, complete	206,158 55

ESTIMATE FOR ENTIRE IMPROVEMENT.

3 locks and dams, at $206,158.55 each	618,475 65
Removing obstacles already existing, as old locks and dams, old bowlder, dams, &c	7,000 00
	625,475 65
Add 10 per cent. for contingencies	62,547 56
Total cost of improvements	688,023 21

This estimate will carry the full depth of water (6 feet) to the lower end of the town of West Newton. It is possible that a little dredging may be needed near Buena Vista, but it will be small in amount, and as the construction of the dams mentioned might cause the removal of this bar in order to secure a supply of gravel, no account has been taken of it in the estimate.

MOVABLE DAMS.

Another mode of improvement, by means of movable dams, is presented.

The system proposed is the same as that adopted at Port-à-l'Anglais, on the Upper Seine.

The dam on the Youghiogheny will be somewhat longer than at Port-à-l'Anglais, the former being 532 feet and the latter 446.

The movable dam proposed consists of Chanoine wickets, erected in a free pass and on a weir, the pass-wickets being 13 feet high and the weir-wickets 7 feet. The depth of water required at the head of each pool is 6 feet; consequently, we will have a lift of 7 feet from pool to pool.

The pass is assumed at 150 feet in width, requiring thirty-eight wickets, and ninety-five will be required for the remaining 382 feet, which will constitute the weir, the wickets being taken as 4 feet wide.

The use of movable dams reduces the lift of the locks from 10 to 7 feet.

As the total elevation required to give 6 feet of water at West Newton is 30 feet, it is evident that five movable dams will give 35 feet of elevation, or five feet more than is necessary, while four dams will give but 28 feet, or 2 feet less than is needed. If, therefore, the slack-water is to stop at West Newton bridge, we must have either five dams of 6 feet lift or four dams of 7.50 feet lift each. I should recommend the latter. If, however, the slack-water is to be extended indefinitely above West Newton, I would recommend the construction of five dams with 7 feet lift, believing these dimensions to be the best for general use. The estimates that follow are for movable dams having the last-named lift. The comparison of cost is, therefore, somewhat unjust to the latter system, as it actually gives 5 feet more elevation than the former.

ESTIMATE OF COST.

For a movable dam, constructed like that across the Upper Seine at Port-à-l'Anglais, height of wickets, 13 feet; lift of locks, 7 feet; breadth of wickets, 4 feet:

NAVIGABLE PASS.

Cost of foundation per running foot.

3.52 cubic yards cut-stone masonry, at $14.40	$50 69
11 cubic yards rubble masonry, at $7.20	79 20
3.13 cubic yards riprap, at $1.25	3 91
7.30 cubic yards concrete, at $6	43 80
64 feet (board-measure) of sill, at $35 per M	2 24
1,500 feet (board-measure) piles, &c., for coffer-dam, at $35 per M	52 50
Total cost per running foot	232 34

Cost of trestle of pass.

1 trestle, 1,300 pounds, at 10 cents	$130 00
2 journal-boxes, 130 pounds, at 7 cents	9 10
2 anchoring-rods, 133 pounds, at 10 cents	13 30
1 anchoring-disk, 80 pounds, at 7 cents	5 60
2 claw-balks, 120 pounds, at 10 cents	12 00
1 hand-rail post, 12 pounds, at 10 cents	1 20
Cost of trestle, complete	171 20

Cost of wicket of pass.

1 horse, 450 pounds, at 10 cents	$45 00
2 anchoring-rods, 133 pounds, at 10 cents	13 30
1 anchoring-disk, 80 pounds, at 7 cents	5 60
3 prop, 600 pounds, at 10 cents	60 00
4 journal-boxes, 220 pounds, at 7 cents	15 40
110 feet (board-measure) lumber for panel, at $50 per M	15 50
Cost of wicket, complete	154 80

Cost of the sole.

1 heurter and slide, 480 pounds, at 10 cents	$48 00
1 tripping-rod, 98 pounds, at 10 cents	9 80
2 guides, 42 pounds, at 10 cents	4 20
1 roller, 26 pounds, bronze, at 40 cents	10 40
Cost of sole and appurtenances	72 40

Total cost of one section 4 feet wide of the pass, excluding the foundation.

Trestle, complete	$171 20
Wicket, complete	154 80
Sole and appurtenances	72 40
Chains, bolts, &c., not considered in the above	50 00
Total cost of one section	448 40
Or, per running foot	$112 10
Cost of foundation, per running foot	232 34
Cost of pass, per running foot	344 44

Cost of pass, 150 feet wide, $51,666.

WEIR.

Cost of foundation of weir, per running foot.

1.10 cubic yards cut stone, at $14.40	$15 84
2.50 cubic yards rubble, at $7.20	18 00
3.70 cubic yards riprap, at $1.25	4 63
5.50 cubic yards concrete, at $6	33 00
64 feet (board-measure) of sills, at $35 per M	2 24
2,000 feet (board-measure) piling, &c., at $35 per M	70 00
Total cost per running foot	143 71

Cost of trestle and wicket of the weir.

There being no data of the weights and dimensions of the wickets of the weir, I assumed that, as they are about three-fourths as high as the wickets of the pass, they would probably cost about three-fourths as much.

Those of the pass (including the trestles) cost $112 per running foot, hence those of the weir should cost per running foot about	$84 00
To this add the cost of foundation per running foot	143 71
Cost of weir, per running foot	227 71

Cost of weir, 382 feet long, $86,985.22.

Cost of pass and weir.

Cost of weir 382 feet long	86,985 22
Cost of pass 150 feet long	51,666 00
Total cost	138,651 22

If a maneuvering-boat be used for the weir, we can omit the trestle bridge above the wickets. This would effect a saving of 95 trestles, which, at an average cost of $128, would amount to $12,160. From this we must take the cost of the boat, which will be about $300, leaving a total saving of $11,860. The suppression of the wickets would also greatly reduce the cost of the foundation of the weir, as the latter would not then be so wide. Assuming that this would reduce the cost of foundation by one-third, we have a saving from this source of $48 per running foot, or of $18,336 in the length of the weir.

Under this condition, the total diminution of cost would be—

On the foundation	$18,336 00
On the trestles	11,860 00
Or, in all	30,196 00
Subtracting this from the cost before given, which is	138,651 22
We obtain as the cost when the boat is used	103,455 22

Cost of five dams, giving a total elevation of 35 feet, $542,276.10.

The locks attached to the movable dams, having a less lift by 3 feet than those in the permanent dams, will cost about one-fifth less than those used with the permanent dams so far as the superstructure is concerned. The foundation will be unchanged. Hence we shall have for cost of the foundation of the lock, $43,316.15; for the superstructure, $68,173.44. The cost of the abutment will remain as before.

SUMMARY.

Cost of dam	$108,455 22
Cost of abutment	16,565 33
Cost of lock	111,489 59
Cost of one lock and dam	236,510 14

ESTIMATE FOR ENTIRE IMPROVEMENT.

5 locks and dams, at $236,510.14 each	$1,182,550 70
Removing obstructions already existing	7,000 00
10 per cent. for contingencies	118,955 07
Total cost of improvement	1,308,405 77
Total cost of improvement by permanent locks and dams	688,023 21
Or the improvement by movable dams will cost more than that by permanent dams by	620,382 56

But in this connection we must notice that by the permanent dams we only reach a height of 30 feet above the surface of the second pool of the Monongahela slack-water, whereas by movable dams we reach a height of 35 feet above the same surface.

The cost per foot of lift with the movable dams is	$37,383 02
And for the permanent dams it is	22,934 11
Or	14,448 91

in favor of the improvement by permanent dams per foot of rise. Hence the cost per foot of rise by the system of permanent dams is approximately only two-thirds of what it would be by movable dams.

In view of the above figures, I would most certainly recommend that the permanent dams be adopted for the improvement of the Youghiogheny River.

Very respectfully, your obedient servant,

F. A. MAHAN,
First Lieutenant of Engineers, U. S. A.

Maj. W. E. MERRILL,
Corps of Engineers, U. S. A.

ANNUAL REPORT

UPON THE

IMPROVEMENT OF THE HARBORS OF MILWAUKEE, RACINE, AND KENOSHA, LAKE MICHIGAN,

AND

IMPROVEMENT OF THE FOX AND WISCONSIN RIVERS,

IN CHARGE OF

D. C. HOUSTON,

MAJOR OF ENGINEERS, BVT. COLONEL, U. S A.;

BEING

APPENDIX X

OF THE

ANNUAL REPORT OF THE CHIEF OF ENGINEERS FOR 1876.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1876.

[EXTRACT FROM THE ANNUAL REPORT OF THE CHIEF OF ENGINEERS TO THE SECRETARY OF WAR.]

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., October 21, 1876.

* * * * * * *

HARBORS OF MILWAUKEE, RACINE, AND KENOSHA, LAKE MICHIGAN—IMPROVEMENT OF FOX AND WISCONSIN RIVERS.

Officer in charge, Maj. D. C. Houston, Corps of Engineers, with Capt. G. J. Lydecker and Lieut. F. A. Hinman, Corps of Engineers, under his immediate orders.

1. *Milwaukee Harbor, Wisconsin.*—The sum of $25,000 appropriated March 3, 1875, has been applied to replacing 400 feet of the old superstructure of the north pier by one of dry stone-masonry, and in constructing 2 substantial pier-heads. The funds available will be sufficient to build 150 feet more of superstructure. The total estimate for replacing 2,240 feet of old superstructure is $120,000. Deducting the appropriations of 1875 and 1876, amounting to $51,000, there remains $69,000 which could be advantageously expended during the next fiscal year.

Amount available July 1, 1875	$24,459 16
Amount expended during fiscal year ending June 30, 1876	16,863 29
Amount available July 1, 1876, including $1,287 due on contracts	7,575 87
Amount appropriated by act approved August 14, 1876	26,000 00
Amount (estimated) required for completion of existing project	69,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1878	69,000 00

(See Appendix X 1.)

2. *Racine Harbor, Wisconsin.*—The appropriation of $10,000 made March 3, 1875, has been expended in dredging between the piers and in completing superstructure over crib placed in 1875.

The appropriation of $8,000 made by act of Congress, dated August 14, 1876, will be applied to rebuilding a portion of the old superstructure of the north pier. An additional amount of $7,000 is required to complete this work and building a pier-head at the extremity of the south pier.

Amount available July 1, 1875	$10,136 32
Amount expended during fiscal year ending June 30, 1876	9,891 75
Amount available July 1, 1876	244 57
Amount appropriated by act approved August 14, 1876	8,000 00
Amount (estimated) required for completion of existing project	7,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1878	7,000 00

(See Appendix X 2.)

3. *Kenosha Harbor, Wisconsin.*—The appropriation of $15,000 made March 3, 1875, has been expended in extending the north pier by 1 crib 50 feet by 30 feet and in dredging the channel between the piers. The appropriation of $8,000 by the act of Congress approved August 14, 1876, will be applied to building superstructure over the two cribs placed in 1874 and 1875; in dredging between the piers, and making necessary repairs.

There is required, in addition, the sum of $7,000 to complete this work.

Amount available July 1, 1875	$15,080 88
Amount expended during fiscal year ending June 30, 1876	14,719 05
Amount available July 1, 1876	361 83
Amount appropriated by act approved August 14, 1876	8,000 00
Amount (estimated) required for completion of existing project	7,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1878.	7,000 00

(See Appendix X 3.)

4. *Improvement of Fox and Wisconsin Rivers.*—The improvement of these rivers is being carried on in accordance with the plan heretofore reported, and the results are given in detail in the accompanying reports.

The enlargement of the Portage Canal has been completed and navigation opened, connecting the two rivers. Two new masonry-locks have been completed on the Fox, and six more will be completed this season. Five new dams will also be completed this season on the Lower Fox, and navigation be re-opened over the entire route. A large amount of dredging has been done on the Upper Fox, in deepening the channel and making cut-offs.

The improvement of the Wisconsin by means of wing-dams has been continued with satisfactory results.

Amount available July 1, 1875		$579,107 43
Amount received from tolls on Fox River for fiscal year ending June 30, 1875	$364 96	
Amount received from tolls on Fox River for fiscal year ending June 30, 1876	385 23	
		750 19
Amount expended during fiscal year ending June 30, 1876		420,415 45
Amount available July 1, 1876		159,442 17
Amount appropriated by act approved August 14, 1876		270,000 00
Amount (estimated) required for completion of existing project		2,975,663 00
Amount that can be profitably expended in fiscal year ending June 30, 1878.		750,000 00

(See Appendix X 4.)

* * * * * * *

REPORT.

APPENDIX X.

ANNUAL REPORT OF MAJOR D. C. HOUSTON, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1876.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., July 13, 1876.

GENERAL: I have the honor to transmit herewith annual reports for the works in my charge for the fiscal year ending June 30, 1876.

I am, general, very respectfully, your obedient servant,

D. C. HOUSTON,
Major of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

X 1.

IMPROVEMENT OF MILWAUKEE HARBOR, WISCONSIN.

The sum of $25,000 was appropriated for this work by the act of Congress, approved March 3, 1875. This has been applied to replacing the old timber superstructure of the north pier, by a wall of dry stone masonry. Four hundred feet of superstructure was built last season, and 150 feet more will be built with the funds now available.

The work this spring has been retarded by bad weather and high water.

Two substantial pier-heads have also been built.

The estimate for the present project, replacing the entire old superstructure, 2,240 feet, was $120,000. There will, therefore, be required to complete the superstructure over both piers, $95,000, all of which could be advantageously expended during the next fiscal year. The old work is very dilapidated and should be replaced without delay.

Money statement.

Amount available July 1, 1875	$24,459 16
Amount expended during fiscal year, ending June 30, 1876	16,883 29
Amount available July 1, 1876, including $1,287 due on contracts	7,575 87
Amount appropriated by act approved August 14, 1876	26,000 00
Amount (estimated) required for completion of existing project	69,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1878	69,000 00

HISTORY OF THE WORKS TO THE YEAR 1875.

This important center of trade is situated upon the west shore of Lake Michigan, at a distance of 100 miles from the head, or south end, of the lake. The natural outlet of the Milwaukee River was at a distance of 3,000 feet to the southward of the present artificial outlet, which has been cut through the sand-drift forming the point which originally covered the north side of the river-channel.

The Menomonee and Kinnickinnic Rivers are two small tributary streams which discharge into the Milwaukee; the points of their confluence being just inside the lake-shore line; the three streams having one common outlet. The main channel is about 230 feet in width and of an average depth of 14 feet at mean water-level. This depth is carried to a distance of about 3 miles from its outlet, at which point a dam has been thrown across the stream to regulate the supply of water for flouring-mills and manufactories. The commerce of Milwaukee was first conducted by means of bridge-piers, which were built from the shore to the navigable water of the lake, and were owned by private parties, but as trade increased, it was found impracticable to conduct it by such means, and a project was formed for improving the mouth of the river.

Some time during the year 1845 or 1846, the mouth of the river was dredged, and protection-piers were built on the sides of the channel to the line of 10 feet of water. Previous to the accomplishment of this work, a survey of the mouth of the Milwaukee River and vicinity was made by Lieutenants Center and Rose, (in 1836,) and a plat of the same submitted, with a recommendation to cut a channel across the point which overlapped the mouth of the river at the distance of 3,000 feet north of the original outlet as before specified. The reasons upon which the recommendation was based, were, that such a cut would provide a more convenient and accessible passage to the interior wharves. This project finally met with the approval of the officers of the United States Engineer Department, and also of the officials of the city of Milwaukee, and on the 30th of August, 1852, the sum of $15,000 was appropriated by Congress for the commencement of this improvement in accordance with the plan recommended; but as such a sum was totally inadequate to produce the desired result, and as the policy of the Government at that time was not particularly directed toward internal improvements, and also as the necessities of the case demanded prompt and energetic action, the authorities of the city of Milwaukee took the matter in hand, which was so essential to their interests, and by consent of the legislature of Wisconsin, levied a tax upon the property of the city, by which means the sum of $50,000 was raised in the year 1855, which was the limit of the expenditure to be made upon the proposed improvement by special tax upon the city property. This sum was placed at the disposal of the United States Government, to be expended under the direction of the United States engineer officer placed in charge of this harbor improvement, in conjunction with the $15,000 appropriated by Congress. In his report to the Secretary of War of date March 15, 1854, Col. J. J. Abert, topographical engineer, states as follows:

> In consequence of failure on the part of contractors to deliver materials at Milwaukee, no pier-work has been put up there, and, as there was adequate time, the Board was desired to revise the plan for the improvement of that harbor. The law on this subject, quoted by the Board, expressly directs the appropriation then made to be expended at a point of the Milwaukee River known as the "North Cut," surveyed by Lieutenant Center.

And in the report of Lieut. Col. James Kearney, topographical engineer, of date March 4, 1854, to Col. J. J. Abert, Chief of the Topographical Bureau, he states as follows:

> The appropriation for the work (August 30, 1852,) is in the following words, viz: "For continuing the improvement of the harbor of Milwaukee, $15,000, to be expended at the point on the Milwaukee River known as the 'North Cut,' surveyed by Lieutenant Center." There have been various other sums appropriated from time to time for the improvement of Milwaukee Harbor. These have been applied to the old or natural entrance to the river.

These reports show that the $15,000 appropriated by Congress on August 30, 1852, had not been expended at the dates of the reports quoted from of March 4 and 15, 1854, and that the new project of improvement by cutting across the sand spit had not been commenced previous to 1854; and also that the two sums, equal in amount to $65,000, were expended at one and the same time. The plan adopted was to dredge across the point and build a crib-pier on each side of the "Cut;" the piers to be parallel to each other upon a magnetic course of N. 81° E., the width of the channel between them to be 260 feet, and to extend to the line of 12 feet of water, mean lake-level. Reports are not available relating to the details of the work, which was commenced and prosecuted vigorously in 1855; but in his annual report for 1856, Brevet Col. J. D. Graham, topographical engineer, quotes from the records of the proceedings of the city council as follows:

> Whereas the city of Milwaukee proposes to expend a certain sum of money, not exceeding $50,000, in the construction of a harbor at a site recommended by Lieutenants Center and Rose, commonly known as the "Straight Cut," and have for that purpose made an appropriation of said sum of $50,000, and have entered into a contract with Abel Hawley to furnish materials, &c., * * * or three sections of the same, reserving it optional with said city whether the said Hawley shall construct the fourth section or not, and which fourth section will complete said harbor.

This extract from the records of the proceedings of the city council shows that that body entered into a contract with Abel Hawley, and it is inferred therefrom that the work and funds were placed in charge of Lieut. Col. J. D. Graham, topographical engineer, for expenditure upon the specified improvement. Owing to the death of a Mr. Barton, who was in partnership with Mr. Hawley, the contract was transferred to Messrs. Hasbrouck & Conro, of Milwaukee, and before the close of the working-season of 1855, 16 cribs, of dimensions 32 feet by 20 feet by 17 feet, were sunk upon a clay bed in fine position, the bed having been dredged to a depth of 12 feet for their reception.

The estimates of the cost of this improvement were low, as has since been proved. The "details" of the progress made upon the work, and the expenditures for the same, cannot be itemized, but the following statement of the total cost involved to the city of Milwaukee by the work from 1855 to 1870, inclusive, may be interesting, almost the whole of which was expended during the years 1855, 1856, and 1857.

The statement is obtained by reference to the accounts of the city comptroller. His accounts show that—

The sum expended by the city for this improvement between the years 1855 and 1870 was $238,355.79.

Of this sum the amount paid to Messrs. Hasbrouck & Conro was	$184,250 00
And the amount paid to other parties was	54,105 79
Total	238,355 79
The amount of Hasbrouck & Conro's bill was	267,249 87
And the amount paid to them up to 1870 was	184,250 00
Leaving a balance due to Hasbrouck & Conro of	82,999 87

This balance the city declined to pay until by process of law a judgment was declared in favor of Messrs. Hasbrouck & Conro, which awarded them not only the principal of the indebtedness, but also interest upon the balance due from 1857 to 1870, and as, by the terms of agreement under the decision of the court, the indebtedness was paid to Hasbrouck & Conro by installments, interest was paid upon the reduced principal until the entire debt was liquidated in 1873.

The total sum awarded to Hasbrouck & Conro by the judgment of the court, including interest, was	$207,615 41
But the original balance due under their contract was only	82,999 87
So that the accrued interest, including extra charges for materials adjudicated by the court, was in amount	124,615 54
Then the entire sum which was paid by the city authorities for materials and labor to all parties before litigation was	$238,355 79
Together with the sum awarded to Hasbrouck & Conro for materials and labor, as per contract	82,999 87
Gives the total payment made for materials, &c., of	321,355 66
But the books of the comptroller show that the city has actually paid for all accounts of materials, labor, and interest	$445,971 20
And by deducting the actual amount paid for materials and labor alone	321,355 66
Verifies the statement of the amount paid by the city for interest and adjudicated prices for materials in balancing the account of Hasbrouck & Conro	124,615 54

The length of each of the piers built by Hasbrouck & Conro was 1,120 running feet, including the pier-heads, which were built 30 feet in width by 30 feet in length, and the channel was dredged for its full length and width to a depth of 12 feet. No further steps were taken by the United States Government for this improvement until the year 1866, during which the sum of $48,283.17 was appropriated by Congress. Of this amount the sum of $9,999.20 was expended in 1867 in supplying stone to the piers under a contract made with Valentine Kuhlman in June of that year. The total number of cubic yards of that material delivered by him was 3,677.

By a plat of soundings which were taken in June, 1867, it was found that the sand-drift from the north was forming a bank which was encroaching upon the harbor entrance, the south boundary of which was tangent to the prolongation of the line of the inner face of the north pier, and during the winter of 1867 and 1868 the bank formed across the mouth of the channel, the depth of water over it being 12 feet. It was decided at this time to extend the piers, and on the 2d of June, 1868, bids were received and opened for extending each of the piers to a distance of 250 feet.

A contract was awarded to Mr. C. H. Starke, of Milwaukee, for furnishing all materials and labor for constructing the same, with the exception of the timber, a contract for furnishing which was awarded to Mr. E. W. Diercks, of Milwaukee. Four cribs, each 50 feet long by 25 feet wide, were sunk in extension of the north pier during the season of 1868, and also 35 days' work were performed by dredging-machines in deepening the channel over the bar. By act of Congress approved April 10, 1869, the sum of $35,640 became available for a continuation of this improvement, and work was resumed under the contracts of June, 1868, which resulted in building and sinking 6 cribs of 50 feet by 25 feet before the end of August, one of which was placed in continuation of the north pier, and the remaining 5 in the extension of the south pier, the whole work forming an extension to each of 250 running feet. Superstructure was also built over the 4 cribs which were sunk in 1868.

Previous to the commencement of operations in 1869, soundings were taken (April 6) to ascertain what changes had taken place upon the bar during the preceding winter. The examination revealed the presence of an addional accretion, the bar having spread entirely across the mouth of the channel in front of the pier extremities, the crest of which was at a distance of 250 feet out, or eastward of the north pier extension, carrying a minimum depth of 10.7 feet of water for a width of 60 feet; this obstruction was a serious impediment to navigation, although at the time of its presence the draught of the vessels comprising the lake marine was not so great as it has since become; it was, however, an obstruction which must of necessity be overcome, and a recommendation was made to extend the piers to a further distance of 350 feet.

The number of arrivals of vessels and steamers at the port of Milwaukee during this year was 5,025; of departures, 5,050.

By act of Congress approved July 11, 1870, the sum of $40,000 was appropriated for this work, and on the 21st day of September, 1870, a contract was let to Messrs. Hasbrouck & Conro, of Milwaukee, to construct 400 running feet, more or less, of pier extension, to consist of 8 cribs, each 50 feet in length by 26 feet in width; but, owing to delays occasioned by the loss of timber through freshets, no work of importance was done. During the night of the 29th of August, 1870, the outer crib of the south pier was run into and seriously damaged by some unknown vessel, the timbers being cut through to a depth of 8 feet below water-surface. The same crib was also run into by the schooner Lottie Wolf, on the 17th day of May, 1871, which collision inflicted more serious injury to the crib, as well as to sink the vessel. On March 3, 1871, another appropriation of $38,000 was made by Congress, and on the 17th of June, 1871, a contract was made with Mr. Henry Starke, of Milwaukee, under which he was to construct an additional extension of 150 running feet to each of the piers, the whole to consist of 4 cribs, each 50 feet by 26 feet, and 2 cribs of dimensions 50 feet in length by 30 feet in width, to complete the pier extension in accordance with the recommendation, and to build superstructure over the whole of the cribs. This work was carried on by the contractors simultaneously, Messrs. Hasbrouck & Conro sinking the first crib of their contract on the 5th day of July, and the eighth and last crib on the 16th of November; Mr. Starke sinking the first crib under his contract on the 30th of July, and the sixth and last on the 23d of November. The third crib from the outer end of the north pier was struck by some unknown vessel and damaged to a serious extent soon after it was placed in position.

The stage of water during this season was low, but a channel carrying 14 feet of water was available for vessels by changing their course but once between the piers.

The number of arrivals during this year was 7,042, with a tonnage capacity of 2,607,850 tons. The number of departures was the same as the arrivals, with a tonnage equal to 2,611,384 tons. During the year 1872, the cribs which were damaged by collisions of vessels were repaired; the third crib from the outer end of the north pier having piles driven close together along its channel-face for carrying the superstructure, and a super-crib being framed to match the broken timbers of the crib on the south side, and which was bolted with long bolts to the sub-crib.

The whole of the superstructure over the 14 cribs was finished and upplied with stone ballast. Guard-piles were driven at distances of 25 feet apart for the entire length of the channel-faces of the new work, which were capped with oak timbers of cross-section area of 12 by 12 inches.

These caps or wals were secured to the superstructure of the cribs by means of screw-bolts, as were also the piles. The ends of the piers were also protected by driving seven clusters of piles, five piles forming each cluster, around the extremity of each pier, the piles of the clusters being sprung together and bound with chains, and otherwise secured in position with screw-bolts. A length of 160 running feet of superstructure, which was in a very dilapidated condition, was cut down and replaced with new work at the western or inner end of the north pier, forming the angle made by the "straight cut" with the river proper. The number of arrivals of steamers and sailing-vessels during this year was 7,475, having a tonnage of 2,579,979; of departures, 7,475, with 2,556,743 tonnage capacity.

By act of Congress approved March 3, 1873, the sum of $10,000 was appropriated for the improvement of this harbor, which was applied to deepening the channel between the piers, under a contract made with Mr. Albert Conro, for dredging, of date May 30, 1873.

The entire length of the channel between the piers is 1,740 feet; its width at the outer end has been increased, through the outward settling of the cribs, to 280 feet.

It is supposed that the piers will not require further extension for many years. The dredging done under Mr. Conro's contract in 1873 produced a depth of water which would have been adequate to float the class of vessels in commission up to 1850, but owing to the increased capacity and draught of vessels of more recent build, the requirements of a channel leading to a harbor of refuge are that the depth of water shall be from 16 to 18 feet. A plat of soundings which were taken in November, 1873, revealed the presence of one or two banks of sand, carrying but 14 feet of water in the center of the dredged channel, which was deepened for 100 feet in width, upon which one or two vessels struck when entering. The appropriation of $10,000 in 1874 was also applied to dredging under a contract made with Mr. Conro, of date August 12, 1874. The number of cubic yards excavated was 29,825. Repairs were also made to two cribs which were ruptured by the collisions of vessels, and wales were replaced to the clusters of piles, the former timbers having been carried away by similar causes.

The result of the dredging was satisfactory, a channel having been provided thereby of more than 17 feet in depth and 140 feet in width for the entire length of the harbor-piers.

The timbers forming the superstructure of the sections of piers built in 1855, 1856, and 1857 being decayed, and requiring replacement, a recommendation was made to rebuild the superstructure with dry stone masonry, and on the 3d of March, 1875, the sum of $25,000 was appropriated by Congress to be applied to this purpose. The first section of this work will probably be commenced at the west or inner end of the north pier, by cutting down the old timber to a depth of 2 feet below low-water line, and by then bolting platforms of oak timbers to the sub-piers for the side walls of masonry to be built upon to a height of 6 feet above mean low-water mark.

The number of arrivals of steamers and sailing-vessels in 1874 was 8,447, having a tonnage capacity of 3,109,189 tons; of departures, 8,331, the tonnage of which was 3,023,422.

In reviewing the short history of this harbor, a comprehensive idea can be formed of the increasing trade of the West.

The first estimates made for the improvement of the harbor were based upon a project for building piers out into the lake to a depth of but 12 feet of water. From this fact it is assumed that the depth of 12 feet was considered as great as ever would be required for the purposes of lake-navigation.

At the present time, many vessels trade at this port which have a carrying capacity of from 40,000 to 70,000 bushels of grain.

X 2.

IMPROVEMENT OF RACINE HARBOR, WISCONSIN.

The appropriation of $10,000, made March 3, 1875, has been expended in dredging between the piers, completing superstructure over crib sunk in 1874, planking over south pier, and repairs of north pier.

A special estimate was submitted by me, dated November 15, 1875, of $15,000, to replace the old superstructure of the north pier, and protect the ends of the piers by pile pier-heads. The anticipated appropriation of this season will be applied to that object.

Money statement.

Amount available July 1, 1875	$10,136 32
Amount expended during fiscal year ending June 30, 1876	9,891 75
Amount available July 1, 1876	244 57
Amount appropriated by act approved August 14, 1876	8,000 00
Amount (estimated) required for completion of existing project	7,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1878	7,000 00

HISTORY OF THE WORK TO THE YEAR 1875.

This important harbor is situated upon the west shore of Lake Michigan, at a distance of 23 miles to the southward of Milwaukee.

The records of the early history of this harbor previous to 1854 are not available. A report of Col. J. J. Abert, topographical engineer, to the Secretary of War, dated May 1, 1854, shows that the balance of funds remaining at that date from a former appropriation by Congress was $7,251.78, and in a report of Lieut. Col. James Kearney, topographical engineer, president of a board of engineers, he states the opinion of the Board in relation to the direction in which the extension of the piers should be built. Also, the Secretary of War approves of the plan submitted by the Board for the extensions of the piers, in which they recommend an additional sum of $18,956.30 to be appropriated for the proposed improvement. In 1866, the sum of $23,910 was appropriated by Congress for the improvement of this harbor, and in August of that year a contract was made with Messrs. Sanger, Ledlie & Corse, of Chicago, for dredging in the channel between the piers and to construct 256 running feet of pier-work in extension of the south pier. In 1867 the sum of $45,000 was appropriated, and on the 27th of June, 1867, contracts were made with Mr. P. M. Danaher, for timber and framing; Messrs. Ledlie & Corse, for stone and brush; and Nelson Gere, of Syracuse, N. Y., for iron bolts.

The construction of 416 feet of crib-extension to the north pier was contemplated under these contracts. During the year 1867, 17 cribs, of dimensions 32 feet in length by 20 feet in width, were built and sunk in position, eight of which were placed in continuation of the south pier, and nine were placed in extension of the north pier, but during a storm in November the outer crib of the north pier was broken and carried away. In the spring of 1868 the old grillage was leveled off and stone placed over it, and a new crib was built and set upon the foundation thus formed; also superstructure was built over both of the pier-extensions. A crib 32 feet square was also added to the north pier as a pier-head. By act of Congress approved April 10, 1869, $2,000,000 were appropriated for the repair, extension, and preservation of works of improvement upon rivers and harbors, to be expended under the direction of the Secretary of War; and of this sum $22,275 was allotted for the improvement of Racine Harbor. The work during this season was the cutting down of superstructure over 288 feet of the older sections of the south pier and replacing it with new work, sheet-piling on the outer side of the same sections, and dredging between the piers.

By act of Congress July 11, 1870, the sum of $10,000 became available for this work. This was applied to building up the 32 feet by 32 feet crib pier-head on the north side, the crib having tilted seriously out of position, and in repairing a break in the south pier at its intersection with the line of shore, and also in refilling the cribs of both piers with stone.

On the 30th of September, 1870, a contract was made with Mr. F. M. Knapp, of Racine, for the construction of 256 running feet of extension to the south pier, to be built 20 feet in width up to the water-surface, which work was completed on the 22d day of July, 1871.

Repairs also were made for a length of 206 running feet of the north pier at its west end, by taking off the old superstructure and replacing it with new. On the 3d of March, 1871, Congress appropriated $10,000 for Racine Harbor, and on the 17th of June, 1871, a further contract was made with Mr. F. M. Knapp for building superstructure over the four cribs, or 256 feet of pier above specified, including also repairs to be made to a portion of the old work on the north pier. A channel of 12 feet in depth was available for vessels during this year. On the 3d of March, 1873, the sum of $20,000 was appropriated by Congress for this harbor, $5,000 of which was applied to dredging in the channel, at the earnest solicitations of the citizens of Racine, the channel having become unavailable for vessels drawing more than 11 feet of water. The silting up of the channel was probably due to the extension which was made to the south pier, for it is well demonstrated that the north, or weather, pier at this harbor should extend to such a distance beyond or outside, of the extremity of the south pier as to prevent a deposit of the sediment which is carried in suspension by the littoral current in front of the entrance to the harbor. On the 29th of May, 1873, a contract was made with Mr. F. M. Knapp, of Racine, for building and sinking two cribs, each of dimensions 50 feet by 30 feet by 26½ feet, or to a height of 1 foot above the water-surface, to be completed and placed in extension of the north pier on or before the 1st day of December, 1873. These cribs were built and placed in position upon foundations of stone before the close of September, their direction being due east.

Sixteen thousand seven hundred and seventy-three cubic yards of material were excavated from the channel by the dredge, which deepened it to the depth of 14 feet and to a width of about 120 feet. Stone was also put into one or two sections of cribs where the ballast formerly put in had run through the grillage-work, leaving one section entirely without ballast.

By act of Congress approved June 23, 1874, the sum of $10,000 was appropriated for Racine Harbor improvement, and Mr. F. M. Knapp being again the lowest bidder, a contract was awarded him on the 12th of August, under which he built and sank one crib of dimensions 50 feet by 30 feet, by 26½ feet, and completed the two cribs sunk in 1873 with superstructure, and decked the outer cribs with plank. The materials used in doing this work were, of timber, 8,310 cubic feet; of iron, 11,663.6 pounds; spikes, 620 pounds; stone, 374.771 cords; brush, 17 cords; framing, 8,260 linear feet; laying plank, 14,417 feet, board measure.

In March, 1875, the amount appropriated was $10,000, which will be applied to building superstructure over the crib sunk in 1874, and making some slight repairs to the older sections of work, and the balance remaining will be applied to dredging in the channel. An idea of the commerce of Racine may be formed by a perusal of the following partial list of exports and imports, obtained from the deputy collector of customs.

During the fiscal year ending June 30, 1873, the imports were—

Of lumber, 38,800,000 feet, (board measure;) square timber, 2,300,000 feet, (board measure;) pickets, (fence,) 250,000; shingles, 12,000,000; laths, 5,200,000; cedar posts, 250,000; hard-wood lumber, 2,500,000 feet, (board measure;) railroad-ties, 60,000; telegraph-poles, 2,000; staves, 149,000; wagon-hubs, 20,000; coal, 24,251 tons; iron, 120,624 tons; tan-bark, 2,000 cords; salt, 15,000 barrels; flour, 2,396 barrels; fruit, 66,850 packages; cotton, 500 bales; stoves, 1,900; leather, 200 packages; dry goods, value $776,000; hardware, value $216,000; groceries, $804,000; boots and shoes, $150,000; paints, oils, glass, oil and sail cloth, $148,000; hats, caps, and furs, $68,000; stationery and books, $130,000; jewelry, clocks, and watches, $50,000; cigars, tobacco, and liquors, $94,000; confectionery and candies, $80,000; furniture of all kinds, $92,000; sewing-machines, $45,000; drugs and medicines, $162,000; millinery, $25,000; cement, $4,000. Total estimated value, $7,694,159.

Exports.—Wheat, 43,507 bushels; oats, 148,590 bushels; corn, 207,200 bushels; potatoes, 4,437 bushels; wool, 400,000 pounds; hay, 2,828 tons; corn-meal, 100 tons; ground feed, 1,000 tons; flour, 1,000 barrels; beef, 1,000 barrels; pork, 2,000 barrels; butter, 250 tons; eggs, 100,000 dozen; brick, 10,000,000; lime, 280,000 barrels; wagons, 12,500; thrashing-machines, 1,200; fanning-mills, 20,000; barrels, 2,075; trunks, 40,000; horses, 25; pumps, 3,000; plows, cultivators, and reapers, valued at $126,000; baskets and turned work, $50,000; sash, doors, and blinds, $219,750; shawls and woolen fabrics, $200,000.

The number of arrivals of steamers and sailing-vessels was 899; of departures, the same number.

As will be seen by the foregoing statement, the city of Racine is eminently a manufacturing city; one firm alone doing a manufacturing business of about $1,500,000 annually.

X 3.

IMPROVEMENT OF KENOSHA HARBOR, WISCONSIN.

The appropriation of $10,000, made March 3, 1875, has been expended in dredging between the piers and in placing one crib 50 feet long by 30 feet wide in extension of the north pier.

The estimate of $15,000 submitted in my last annual report, or so much as may be appropriated this year, will be applied to building superstructure over the two cribs, 100 feet in length, in extension of the north pier, repairs of pier, and dredging in the channel.

Money statement.

Amount available July 1, 1875	$15,080 88
Amount expended during fiscal year ending June 30, 1876	14,719 05
Amount available July 1, 1876	361 83
Amount appropriated by act approved August 14, 1876	8,000 00
Amount (estimated) required for completion of existing project	7,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1878.	7,000 00

HISTORY OF THE WORK TO THE YEAR 1875.

This harbor is situated upon the west shore of Lake Michigan, at a distance of about 33 miles to the southward of Milwaukee and about 50 miles to the northward of Chicago. As there is no other harbor to which vessels can resort between Kenosha and Chicago, its position is of importance as a harbor of refuge, although its present limited capacity restricts it from being considered a first-class harbor of that denomination. Pike Creek is a small brook which runs through the city of Kenosha, and which during the season of spring freshets discharges a small volume of water into "the basin." At other seasons of the year there is little or no current from the river; consequently, the only scouring effect produced upon the bed of the harbor channel is that produced by such tidal influences as are due to the changes in direction and force of the wind. The "basin," as it is termed, is the southern section of an extensive bayou, trends northward from the harbor-channel, and which is separated from Lake Michigan by a point of sand which has been formed by the action of the water in a similar manner to the formation of the bars which are common to the outlets of all streams upon this lake. The natural depth of the water in this basin is about 5 feet, but a depth of about 10 feet has been produced over a small area of its extent by artificial means.

The character of the material forming the bed of the basin is soft, which renders it practicable to increase the depth of water at a comparatively low rate of expenditure.

The first partial records attainable in this office, respecting the improvement of this harbor, are those found in the report of the Secretary of War for the years 1854 and 1855, in which is printed a report of Col. J. J. Abert, Corps of Topographical Engineers, United States Army, to the Secretary of War, dated August 4, 1854. This report shows that an appropriation had been made by Congress for this harbor improvement in August, 1852; for he quotes from some interrogatory letter addressed to him by the chief clerk of the War Department, as follows:

> First point. What part of the plan is it contemplated to execute with the unexpended balance on hand?

And replies—

> This question being fully answered, and in much detail, by a report from the board of the 3d instant, I have the honor to submit a copy of it.
>
> Second point. Have any assurances been received that the remaining sum necessary to complete, will be furnished by the local authorities or citizens of the place? (Reply.) I am not aware of the existence of any such assurances; there are none in this office of recent date, that is, since the passage of the appropriation of August, 1852. Before that date there were intimations of this kind, and expenditures of a serious amount were actually made by the citizens of that place.

To which report is affixed an appendix written by the Secretary of War, as follows:

> The plan for the improvement of the harbor with the balance of the appropriation is approved, it being understood, though not stated, that the work proposed will be complete in itself without any further expenditures.

And the Secretary of War further states that—

> The board does not agree with Lieutenant-Colonel Graham in reference to the dredging inside, within the river at Kenosha. * * * * *
>
> But the board is of opinion that none of the suggestions of Lieutenant-Colonel Graham (except the last) will, as explained in the letter of Colonel Graham and in the report of the board, occasion any expenditure beyond the estimate of the approved plans; and all of these suggestions (except the last) were reviewed favorably by the board. It is therefore respectfully recommended that the revised report of the board be approved under those restrictions.

It is assumed that the balance of funds remaining on hand in 1854, from the appropriation of August, 1852, were applied to the repairs of portions of the older sections of the work, and in dredging across the bar in front of the piers. Since the reports of 1854 were made, very important changes have been effected upon the shore-line of the lake, through the agency of the piers.

On the north side of the channel the beach has been widened or extended eastward fully 300 feet by sand accretions, and the depth of the lake-water in the vicinity of the harbor has been sensibly diminished from the shore outward, rendering the extension of the piers imperative. No further steps were taken for the improvement of this harbor until the year 1866, when the sum of $75,461.21 was appropriated by Congress for this purpose, and contracts were made with Messrs. Sanger, Ledlie & Corse for the extension of both of the piers of the harbor, by building and sinking cribs on the pier alignments, and with Caleb H. Parker for dredging between the piers and across the bar. The length of the proposed extension to the north pier under the contract was 192 feet, and to the south pier, 352 feet.

This work was done during the years 1867 and 1868. The outer crib of the north pier, after being placed in 1867 and accepted, was moved from its position during a heavy gale. The contractors were required to rebuild this crib before payment was made in full, which they did, but during the succeeding winter the crib was again broken. It is assumed that the loss of the crib was attributable to the manner in which the crib was bolted, the augers used for boring the holes into which the bolts were driven being of too large a size, and the bolts used at that time not being swaged or headed.

Under act of Congress of date April 10, 1869, the sum of $5,346 was allotted for this harbor, which with the appropriation of July 11, 1870, in amount $10,000, was in part applied to the cutting down of 552 running feet of superstructure of the old work of the south pier and replacing the same with new work.

On the 3d of March, 1871, the sum of $10,000 was appropriated by Congress, and a contract was made with Mr. R. A. Conolly for extending the north pier by driving close piling and surmounting the same with superstructure around the outer crib sunk in 1867, which was first broken, and subsequently removed by the sea to a distance of 9 feet east of the position in which it was first placed, and also to construct and place an additional crib 50 feet in length by 30 feet in width in connection with the same upon the pier alignment, which work was completed on the 22d day of December, 1871, and on the following spring superstructure was built over the two cribs.

By act of Congress, approved June 10, 1872, a further appropriation of $10,000 was made for the improvement of Kenosha Harbor, and on the 10th of August a contract was made with Mr. F. M. Knapp, of Racine, for building and sinking one crib, of dimensions 50 feet by 30 feet, upon a foundation of stone, and to make repairs. The crib was sunk on the 3d day of November, 1872, in good alignment, and repairs were made to the old work at the west end of the north pier adjoining the basin, by taking off the old superstructure, which was in a dilapidated condition, for a length of 361.6 feet, and replacing it with new work 4 feet in height and 12 feet in width. The bar in front of the harbor entrance continued to form outside of the extremities of the piers, although the last crib was sunk and placed in 17½ feet of water. In the spring of 1873 superstructure was built over the crib sunk in 1872.

By act of Congress of date June 23, 1874, the sum of $10,000 was appropriated for this harbor, and a contract was awarded to Mr. F. M. Knapp, under which he was to build and sink one crib, of dimensions 50 feet by 30 feet, in extension of the north pier, and make repairs necessary to the older work. The crib was sunk in good position on the 25th of September upon a foundation of stone previously laid, and a section of the old work of the north pier, 430 feet in length, extending west or inward from the original beacon-light crib, was cut down to low-water mark, and new superstructure was built upon the original substructure.

In March, 1875, Congress appropriated $15,000 for Kenosha Harbor. With this sum it is proposed to extend the north pier by sinking one crib of 50 feet by 30 feet, and to dredge in the channel.

The total length of the north pier from the point of its commencement at the basin to the eastern extremity is 1,275 feet. The length of the south pier is 1,150 feet. The length of the north pier outside of the shore accretions is now but 450 feet. The accretion on the south side of the harbor has naturally been less than on the north, the distance from the shore-line to the east extremity of the pier being 775 feet.

A bar still exists, or rather has been reformed outside the mouth of the harbor, which is said to carry but 9½ feet of water over its crest.

As a depot for the agricultural products of the interior district of country, Kenosha is somewhat unfortunately situated. The great commercial centers of Chicago on the south, and Milwaukee on the north, absorb and control to a great extent the business which would seem to belong properly to Kenosha. The railroad interests also conflict with the elements which should conduce to the prosperity of the place. The manufacturing industries of Kenosha are by no means to be ignored, and as soon as the harbor is completed, so as to admit vessels of all classes, the commercial sources of the city will be secured proportionally with the facilities offered, and also the lake marine generally will be benefited thereby.

X 4.

IMPROVEMENT OF FOX AND WISCONSIN RIVERS.

The work of improving these rivers has been prosecuted in accordance with the general plan described in former annual reports. The accompanying reports of Capt. G. J. Lydecker and First Lieut. F. A. Hinman, Corps of Engineers, describe in detail the work done during the year. These officers have rendered me the most efficient and cordial assistance in the duty of conducting this work.

As stated in my last annual report, contracts were made in June, 1875, for the construction of four new locks of stone masonry on the Upper Fox, and the reconstruction of the upper combined lock at Little Chute, on the Lower Fox. The contract-prices for these locks were so low that additional contracts were made for the reconstruction of the second lock at Appleton, the third and fourth locks at Kaukana, and the dams at the Cedars, Little Chute, Rapid Croche, and Little Kaukana. Owing to the low prices at which these contracts were taken and want of means, the contractors failed to fulfill their contracts. The contracts were annulled, and the work continued by open purchase and hired labor. Owing to the failure on the part of the contractors, the work was greatly delayed; but the past winter having been mild, a considerable amount of work has been accomplished, and the works will probably be finished nearly, if not quite, as soon as if the contractors had been successful. The cost of the works will be greater than it would have been at the contract-prices, but not greater than the estimates.

The present condition of the works on the Fox is as follows:

The excavation and revetment of the Portage Canal has been completed, except a portion of the revetment at the western end, where it is proposed to make a basin; the locks at Portage and Governor's Bend have been put in working order, and the Upper Fox, between Winnebago Lock and Governor's Bend Lock, deepened to allow the passage of boats; the new locks at Grand River and Princeton are ready for laying the walls, which will probably be accomplished in September next; the masonry-walls of the new lock at White River are completed; the new lock at Berlin is ready for the masonry-walls; the walls of the new lock at Eureka are completed; a considerable amount of dredging has been done on the Upper Fox in deepening the channel and excavating canals at Eureka and Berlin; the walls of the second lock at Appleton are well under way, as well as those of locks at Little Chute and Kaukana; work on the new dams on the Lower Fox has been retarded by the unusual high water of this season, which has also kept back the work on the locks of the Upper Fox. It is expected that all of these will be completed this season, which will open navigation on the Lower Fox. It will not be necessary to close navigation on this portion of the route for any length of time, as the new locks to be built can be located alongside of the old ones.

It is proposed this season to put in the dams at Eureka, Berlin, White River, Princeton, and Grand River, which will make slackwater throughout the Upper Fox.

A new and powerful dredge has been built during the past season, and it is proposed to use this with the other dredges to deepen and widen the channel of the Upper Fox.

It is also proposed to put in a new guard-lock at the Wisconsin end of the Portage Canal. This canal has been widened, deepened, and revetted.

The completion of the works now in progress and contemplated this season will complete the *system* of slackwater navigation from Portage City to Green Bay, and render the river navigable at all seasons for light-draught vessels. The next step in order will be the deepening and widening of the channel by dredging and rock excavation, and the gradual replacing of the old locks by masonry-locks.

The amount of tolls collected during the year ending June 30, 1876, is $385.23, required to be reported annually by act of Congress approved July 7, 1870. Navigation has been interrupted throughout the year by the rebuilding of locks.

Under the act of Congress, approved March 3, 1875, entitled "An act to aid in the improvement of the Fox and Wisconsin Rivers, Wisconsin," which provides that—

> In case any lands or other property is now or shall be flowed or injured by means of any part of the works of said improvement heretofore or hereafter constructed for which compensation is now or shall become legally owing, and in the opinion of the officer in charge it is not prudent that the dam or dams be lowered, the amount of such compensation may be ascertained in like manner.

A large number of claims have been made against the Government for flowage damages principally caused by the dams at the outlets of Lake Winnebago. My views on this subject are contained in a report to the Chief of Engineers, dated May 1, 1876, a copy of which accompanies this report.

The cost of a new canal, in addition to the estimates already presented for the completion of this improvement, is estimated at $106,558, and the cost of deepening the present canal and Menasha channel to full width, so that boats could pass if the dams were removed, is estimated as follows:

66,000 cubic yards of dredging, at 20 cents	$13,200
Coffer-dam	3,000
Excavating 18,500 cubic yards of rock, at $1	18,500
Contingencies	5,300
	40,000

I would recommend the excavation of a new canal as an ultimate measure to complete the improvement, but in order to settle this question of flowage it would probably be advisable to deepen the present canal, which can be done at comparatively small cost and in a short time. The special assistant attorney-general, appointed by the Attorney-General, to represent the interests of the United States under the act above mentioned, the Hon. R. L. D. Potter, expresses his concurrence with my views on this subject.

The work on the Wisconsin River was prosecuted during the season of 1875 on the plan of contracting the channel by means of wing-dams and jetties, and obtaining an increased depth by the scouring action of the current. The results of last season's work were reported by me to the Chief of Engineers in a letter dated December 15, 1875, a copy of which accompanies this report. I also submit herewith a paper illustrated by drawings on the improvement of the Wisconsin River, showing the practical operations of the work.

No work has been done on the Wisconsin the present season, the funds available being all required for the prosecution of the work inaugurated on the Fox, and the portion of the last appropriation set apart for the Wisconsin River having been expended last season.

A recent examination of a portion of the Wisconsin River shows that the results of last season's work in improving the channel have not been injuriously affected by the high water of this season, and warrants the opinion that the navigation of the river can be permanently improved by the method adopted.

Work will be resumed on the Wisconsin as soon as an additional appropriation becomes available.

I am greatly indebted to my assistants, Captain Lydecker and Lieutenant Hinman, of the Corps of Engineers, for their efficient and zealous co-operation in the conduct of this work, and also to the civil assistant engineers and others employed in the immediate supervision of the different works.

There have been, during the past year, 16 different works, each requiring a special overseer or inspector, also a special party engaged in constructing 30 lock-gates; the construction of a dredge by contract, requiring a special inspector; the operating of two dredge-boats and one steamer, besides various minor operations. These works, distributed over a line 270 miles in length, require a large force for superintendence.

During the year an accurate survey of the Fox River has been completed and the results plotted on a scale of 1 inch to 200 feet.

The complete survey of the Fox and Wisconsin Rivers on this scale is (for the plan) plotted on 59 sheets, in all 472 feet in length. Beside this are several sheets showing profiles and cross-sections. Numerous local surveys necessary in the progress of the work have also been made by the assistant engineers. The following estimate is submitted for the fiscal year ending June 30, 1878, to carry out the general plan submitted in my estimate to the Chief of Engineers, dated January 6, 1875. (Report of Chief of Engineers for 1875, page 521.) This is the only estimate that has been submitted for completing the work; partial estimates only had been previously submitted. This estimate was $3,599,105. Since it was made, the sum of $500,000 has been appropriated, leaving the amount remaining to be appropriated for completion, $3,099,105. To this should be added the sum $146,558 for deepening present canal and channel, and for new canal at Menasha. I estimate that $750,000 can be advantageously expended during the fiscal year ending June 30, 1878.

There have been appropriated for this work by acts of Congress approved—

July 10, 1870, improving Wisconsin River	$100,000
June 10, 1872, purchase of property and franchises of Green Bay and Mississippi Canal Company	145,000
March 3, 1873, improving Fox and Wisconsin Rivers	300,000
June 23, 1874, improving Fox and Wisconsin Rivers	300,000
March 3, 1875, improving Fox and Wisconsin Rivers	500,000

The following papers are submitted with this report:

No. I. Report of Maj. D. C. Houston on improvement of Wisconsin River, dated December 15, 1875.

No. II. Paper on improvement of Wisconsin River by Maj. D. C. Houston.

No. III. Report of Maj. D. C. Houston on question of lowering the dams at outlets of Lake Winnebago, dated May 1, 1876.
No. IV. Report of Captain Lydecker, dated July 5, 1876.
No. V. Report of Lieutenant Hinman, dated December 9, 1875.
No. VI. Report of Lieutenant Hinman, dated July 3, 1876.
No. VII. Report of Lieutenant Hinman, dated July 5, 1876.

Money statement.

Amount available July 1, 1875		$579 107 43
Amount received from tolls on Fox River for fiscal year ending June 30, 1875	$364 96	
Amount received from tolls on Fox River for fiscal year ending June 30, 1876	385 23	
		750 19
Amount expended during fiscal year ending June 30, 1876		420,415 45
Amount available July 1, 1876		159,442 17
Amount appropriated by act approved August 14, 1876		270,000 00
Amount (estimated) required for completion of existing project		2,975,663 00
Amount that can be profitably expended in fiscal year ending June 30, 1878		750,000 00

I.—REPORT OF MAJOR D. C. HOUSTON, CORPS OF ENGINEERS, DATED DECEMBER 15, 1875, ON IMPROVEMENT OF WISCONSIN RIVER.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., December 15, 1875.

GENERAL: I have the honor to transmit herewith a report, by First Lieutenant F. A. Hinman, Corps of Engineers, of the operations on the Wisconsin River during the present season, with the reports of overseers in charge of parties.

Accompanying this report are two tracings, marked Nos. 1 and 2, showing the works constructed and soundings taken in October last.

The operations of the past season have consisted in perfecting, as far as possible, the system of improvement on those sections of the river where work had been done in former seasons by putting in additional dams and shore protections, and making such modifications in methods of construction as experience has suggested.

Heretofore the work has been more distributed, with the view of getting the river gradually under control and confining the water to a single channel.

Persons along the route and others had become impatient at the slow progress of the improvement, and had aroused a sentiment of opposition to the plan adopted, and were clamoring for the construction of a canal along the river-bank. It was determined, therefore, to confine the work to short sections of the river, and perfect the system as far as possible, in order to demonstrate the success or non-success of the system.

The plan adopted consists in reducing the width of the river and confining the channel. The bed of the river being light sand, it requires no demonstration here to show that an increased depth will result. We find wherever the river is narrow, and wherever it has been contracted by artificial means, that the channel is deeper than in the wide portions.

If, therefore, the waters of the river were to be confined between two parallel dikes, it is evident that an improved channel, as to depth of water, would result. But it is necessary to dispose of the sand which is scoured out by the concentration of the current, and for this reason, instead of building parallel dikes to contract the channel, spurs made of brush loaded with stone are projected from the banks so that the sand may be deposited in the intervals between them, forming new banks and ultimately producing the same effect as the parallel dikes. At the ends of the spurs or wing-dams are arms extending down stream, designed to prevent a too rapid dispersion of the current.

Where the current impinges against the banks, the latter are protected by layers of brush loaded with stone so as to confine the channel at those points.

The difficulties in the application of this method, simple in itself, consist in the proper arrangement of the dams, their distance apart, their height, &c., and the amount of contraction to be given to the channel. These points are only determined by experience in the particular case. It is submitted that the result of last season's work, as shown by the accompanying reports and tracings, warrants the opinion that the method adopted will, if persevered in, result in such improvement of the navigation of the Wisconsin River as will meet the requirements of commerce.

Referring to tracing No. 1, showing the work from Portage City to Sauk City, a distance of 27 miles, it will be observed that the stage of water at the date of the soundings was only 2.4 inches above low water of 1872. For a distance of 12 miles below Portage City additional dams and shore-protections have been put in, perfecting, as far as practicable, the system of improvements. It will be observed that in this distance of about 12 miles below Portage City, out of 284 soundings, there are 40 less than 4 feet, 15 less than 3½ feet, and but 2 less than 3 feet. It is to be remarked that many of these dams having been recently built, the current has not had time to produce its full effect, but since the date of the soundings it is reported that there is not less than 3 feet of water in the channel on this section. After the current has produced its effect, it will be seen what additional works are needed. Now it is well known that before these works were built, this portion of the river at that stage of water was obstructed by a succession of sandbars, entirely preventing navigation of any kind. Moreover, a comparison of the present soundings, with soundings taken in former years, indicates a marked improvement in the channel.

It is evident to me that if we can produce a channel of 3½ feet by the method we have pursued, an additional depth may be secured by still further contracting the channel, the material to be scoured out remaining the same.

I am informed through the press that a petition will be presented to Congress this session condemning the system of improvement adopted on the Wisconsin River, and asking for the construction of a canal from Portage to the Mississippi, a distance of 118 miles. The impression also prevails that the money already expended on the Wisconsin will, in that case, be thrown away.

In my opinion an improved river-channel, with navigation uninterrupted by locks and accidents to which a canal is subjected, is much more desirable than a canal, and no efforts should be spared to attain it, so long as a possibility of success exists. Particularly is this the case when we consider the relative cost of the two plans. But it is probable that these points will be thoroughly considered before Congress takes any action in the matter. I desire, however, to correct the impression that the money expended on the Wisconsin River will have been thrown away in case a canal should be built. The navigation of the river will be an important aid in the construction of the canal for the transportation of materials and supplies required in its construction, and, therefore, whatever is done to improve that navigation would be an essential aid.

That the navigation of portions of the Wisconsin River has been improved to a certain extent by the plan adopted, and that the rest can be is a fact, whatever representation to the contrary may be made. That there should be an impatience exhibited is natural, but it is doubtful whether this would be relieved by adopting the canal plan. In the first place, detailed surveys and estimates are required, and then large appropriations. In the absence of detailed surveys, my opinion is that the proposed canal would cost not less than $10,000,000. That such a canal is perfectly practicable, and that it would provide a reliable waterway is undoubted; but it is a serious question whether the results to be obtained would warrant any such expenditure, and whether, with such an expenditure, the desired results could not be better and more expeditiously secured in some other way.

A strong argument of the original advocates of carrying on this work by the General Government was its great economy, but if to $10,000,000 be added the amount required for the improvement of the Fox River, we have $14,000,000 for a transportation-route from the Mississippi to Lake Michigan, a distance by the shortest line of 138 miles—$100,000 to the mile. With this sum a double-track road of the most ample capacity could be constructed and equipped, available at all seasons of the year, subject to no accidents that could not be repaired in a few days, and the cost of transportation would be reduced to actual running expenses.

In the report of the Select Committee of the Senate on Transportation-Routes to the Seaboard, Senate Report 307, part 1, Forty-third Congress, first session, it is stated with regard to the central route that if the freight-railway from the Kanawha to tide-water be adopted instead of the canal and slackwater improvement, the cost of transportation from the Ohio River to the ocean will, it is believed, be substantially the same as above stated, *i. e.*, the cost of transportation by a freight-railway 509 miles would be the same as by canal 348 miles and slackwater 161, while the cost of the canal and slackwater route is estimated at $55,000,000, and that of the railway only $25,000,000, less than one-half.

The idea, then, of connecting the great water-highways of the continent by freight-railways instead of by canals has the highest authority, and if, as above stated, the cost of transportation is substantially the same in either case, the question of cost of construction would seem to be decisive. In neither of the cases where a freight-railway has been suggested by the committee, viz, the southern and central routes, is the case so favorable as between Lake Michigan and the Mississippi, either as regards distance or cost of construction. In the central route, the distance to be overcome is 509 miles, in the southern route, 430 miles; while between the Mississippi and Lake Michigan, the shortest distance by rail is only 138 miles.

The committee states in regard to the central route that the question as between canal and railway is to be decided after the completion of careful surveys and estimates.

The only argument in favor of the improvement of the Fox and Wisconsin Rivers, is that it can be done at a moderate cost by improving the natural navigation of these rivers. If it becomes necessary to make a canal to accomplish the object at a large cost, it is evident at once that the desired results could be better secured by adopting the alternative plan of a freight-railway as suggested by the committee in reference to the other routes. The railway would cost less. Having to pay no dividends or interest, the cost of transportation would be as low as on a canal and it would be available at all seasons.

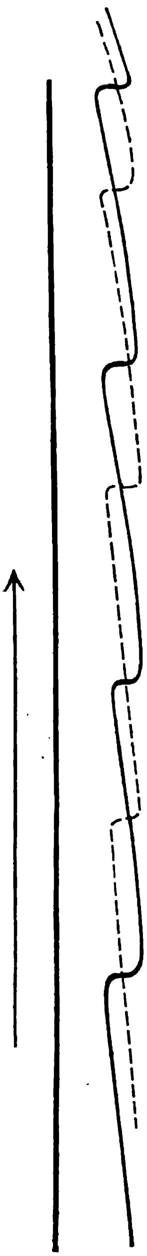
I think it would be well to consider this question before resorting to the costly expedient of a canal, in case further operation should demonstrate the failure of the present plan of improvement.

I am, general, very respectfully, your obedient servant,
D. C. Houston,
Major of Engineers, U. S. A.

Brig. Gen. A. A. Humphreys,
Chief of Engineers U. S. A.

II.—METHOD OF IMPROVING THE NAVIGATION OF THE WISCONSIN RIVER, BY MAJ. D. C. HOUSTON, CORPS OF ENGINEERS.

The plan adopted and being carried out in the improvement of the navigation of this river is to reduce its width and increase its depth by the scouring action of the current. The river has a bed of sand, and its navigation is obstructed by sand-bars, or, properly speaking, sand-waves. The general form of these bars is shown by the accompanying longitudinal section of a portion of the river.



The full and dotted lines show the changes that are constantly taking place in the position of the bars. The up-stream slope is very gentle, and the down-stream slope abrupt. The effect of the current is to move the sand up the up-stream slope until it reaches the crest, when it falls into the deep water immediately below; consequently the crests of the bars are continually moving down stream. The depth of the crests below the surface varies with the width of the channel. The narrower the channel the greater the depth on the bars. The object of the works of improvement is not, then, as in many cases, the removal of the bars, but to lower them. The bars or sand-waves will still exist and move as before, but their crests will be forced down so as to admit the discharge of the river when confined in narrower limits.

This brief statement is given as a preliminary to an account of the practical methods adopted in carrying out the plan. In the first place, all lateral channels are cut off by dams, so as to confine the river to a single channel at low water. Where the river is too wide, spurs or wing-dams are projected from the banks until the required contraction is obtained. From the end of these spurs an arm is extended down stream to prevent the too rapid dispersion of the current. The general arrangement of these works is shown in Fig. 8.

The effect of these contractions is to scour out the sand which is deposited between the dams, forming new banks, and consequently a reduced width of channel throughout. An immense quantity of sand is thus disturbed, and a considerable time is required to form the new channel. The immediate effect of the work may, therefore, be prejudicial to navigation, and give rise to the opinion among superficial observers that the system is a failure. The wing-dams generally make an angle with the shore up stream somewhat less than a right angle. This throws the water passing over them at high water away from the river-bank and diminishes the abrading effect. It is also found to facilitate construction by reducing the scour along the face of the dam. At the angles of the main dams with their down-stream arms short spurs are placed, which prevent undermining. When the current impinges strongly against the bank the latter is protected, when of yielding material, by a facing of brush and stones. Fig. 7 illustrates the effect of these works upon the current and the manner in which the sand scoured out is deposited between the dams. The material used in the construction of these works is brush loaded with stone. Only sufficient stone is used to hold the brush in place until it becomes filled and surrounded by deposits of sand. Experience here and in Europe has shown that this material is the best adapted for such work, besides being the only one which can be used on such extensive works on account of its small cost. The brush is first bound into fascines, which are combined into mats, as shown in plate 3.

First Lieut. F. A. Hinman, Corps of Engineers, has prepared the following description of the practical method of constructing these works:

1.—ORGANIZATION.

The working party, numbering 150 men, is under the immediate charge of an overseer, (assisted by a suboverseer,) and is subdivided as follows: 2 boat-crews, 2 crews of 12 men each constructing dams and shore-protections, 2 crews of 4 men each loading mats and stone, 1 snagging party, 1 ship-carpenter, and 1 blacksmith. The balance of the force is employed in quarrying stone when necessary, in the brush in making mats, and also in delivering them on the bank of the river.

2.—OUTFIT.

The outfit comprises the following-described light-draught boats, fully equipped with the requisite lines, blocks, anchors, pike-poles, axes, hatchets, picks, shovels, wheelbarrows, &c.: 1 steam tow-boat, with grouser forward and a drum for winding; 1 steam-scow, (for use in felling leaning timber, snagging, &c.,) with grousers fore and aft, and a spool for winding; 5-70 feet by 18 feet scows, with grousers and capstans fore and aft; 5-45 feet by 14 feet scows, with grousers fore and aft; 2 quarter-boats, with grousers fore and aft; 1 floating warehouse, with grouser fore and aft; 1 floating carpenter and blacksmith shop, with grouser fore and aft.

A grouser (Fig. 1) is a heavy oak timber, usually iron-pointed, that passes through the hull, or down the side of a boat, near the end, for the purpose of anchoring it, or, when two are used, for holding a boat in any position with regard to the current.

The grouser-frame is used in operating it. The grousers of the quarter-boats, warehouse, and shops pass down their sides.

A mat-pole is 20 feet long, 3 inches in diameter, and should be smoothly shaved and iron-pointed.

A mat-hook is lighter than a mat-pole, but is otherwise similar to it, except that it has an iron hook large enough to hook on the binding-pole of a mat.

3.—STONE AND WOOD.

Stone is purchased delivered in regular piles at convenient points along the river. The piles should be very near the water's edge, parallel with the shore-line, and not over 8 feet in width, for convenience in loading. Flat stone are preferable, as they lie closer and make more even work than if otherwise. Their weights should range from 5 to 75 pounds, for convenience in handling.

As the working season is short, it is important, and economical too, that stone and wood should be purchased and delivered in the winter, in order to save long hauls by team or by boat, when roads are bad or when boats cannot well be spared. All materials should be piled above the proposed work when it can be done advantageously, in order to render towing easier. Stone is loaded on the large scows, except for work in very shoal water, when small scows are used.

4.—FASCINES.

Fascines are made of *green* brush, from half an inch to 2 inches in diameter at the butt, bound together by 3 withes. They are cylindrical in form, about 10 inches in diameter, and 12 feet in length. They are manufactured as follows: the party is divided into binders and cutters, one of each working together. Each binder provides himself with 6 stout stakes, 3½ feet long by 2 inches in diameter, with which he makes 3 crotches (Fig. 2) by driving them firmly into the ground 4 feet apart, and binding them with lath-yarn at their intersections. The upper opening of the crotches should be 18 inches by 18 inches. The cutters are placed in line in the brush 100 feet apart; each binder is placed 50 feet in advance of his cutter, thereby enabling the latter to work over a square 100 feet on a side, the binder and his bench being in the center. Each cutter piles his brush near the bench, butt-ends one way, within easy reach of his binder. The cutter provides willow, birch, or hazel withes ¼ inch to ½ inch in diameter at the butt, and also 4 binding-poles for every 6 or 7 fascines made by his partner. These poles should be 6 feet long by 2½ inches in diameter. They are trimmed, and 2 laid between every 6 (or 7, as the case may be) fascines piled by the binder. The binder first selects a sapling the full length of a fascine and lays it in the crotches of his bench, taking care to bend in all the branches. This affords a foundation for the smaller brush that is to compose the fascine. He places each piece in, one at a time, so as to break joints, butts one way. When the bench is nearly full another long sapling is put on, and the whole mass crowded together with the knee, and bound with withes near each crotch. Should the withes be brittle, they will become pliable if soaked overnight in water. Two men will make 64 fascines in 8 hours.

The fascines and binding-poles are transported to a good boat-landing on a wagon having an ordinary wood-rack. The fascines should be piled (butts one way) on an open piece of ground as near the proposed dam as possible.

5.—MATS.

A mat (Fig. 3) is composed of 6 or 7 fascines laid side by side, and tightly bound between 4 poles tied together at the ends and middle with lath-yarn; its dimensions are about 12 feet by 5 feet by 8 inches. The size of the mats depends on the kind of brush available. Those of soft wood are larger than those of hard, the intention being to have them so that four men can easily handle them. The mat-makers work in pairs; each pair has a mat-frame (Fig. 4) or a set of 4 rollers, (each 1 foot in length,) together forming on the ground a rectangle 4 feet by 6 feet, (Fig. 5.) In making mats, the mat-frame (or set of rollers) is placed at the end of a pile of fascines and on it are laid two binding-poles; on and across these are squarely placed 3 fascines, butt ends one way; a strand of lath-yarn 3 feet long (several strands are carried about the neck) is then tied to the middle of each binding-pole and temporarily caught on the top of the nearest fascine. Three (or four) more fascines are then similarly placed beside the others, after which 2 more binding-poles are placed directly over the others and made fast to them respectively at the ends of the same side, one man holding up the opposite end of each upper pole, so that when forced down against the fascine the lath-yarn will draw tight. A round turn is taken on each pole to prevent the tie from slipping. Both men then proceed to the unbound side at the butt; one sits down, takes the two butt binding-poles in his hands, and with his feet crowds the fascines together, assisted by the other man, who ties the two ends near the outer fascine; this process is repeated at the brush-end binding-pole, after which each man ties the respective poles together in the middle, and cuts them off at the end as close to the tie as possible. The mat is then turned up on edge, propping up the first for a backing, the frame pulled along, and the operation repeated. Two men will make 80 mats in 8 hours. The above method of making fascines and mats not only greatly facilitates handling and transporting the brush, but it also keeps the same in good shape when subjected to the strains that follow in constructing dams, &c., and moreover makes the dams, &c., compact and even. When mats are made over 8 inches in thickness they are apt to be loose, and do not make so tight a dam as otherwise, there being necessarily too great a proportion of brush to stone, as the latter is laid on evenly, and only so many can be used to advantage. Small scows are used in transporting mats. The most convenient and economical way of loading mats is for 4 men to carry them by binding-poles, placing 6, one upon the other, at the end of the scow; these form a backing against which the balance rest, placed 2 abreast on the butt end.

6.—COMPONENTS OF A DAM.

A dam (Fig. 6) is built about 2 feet above low water, expecting it to settle some; it is usually composed of the shore protection A, the wing-dam B B′, the spur D, and lastly the slant B′ C. The shore-protection extends from the shore-end of the wing-dam to a point 40 or 50 feet below it, depending in length upon the location, bank, and importance of the dam. Too much importance cannot be attached to the shore-protection, as in time of freshets, when the water passes over the wing-dam, an eddy is formed, which would eat away the bank and ultimately work around the end of the dam were it not for the shore-protection. The wing-dam is slanted from the shore very slightly up-stream to produce slackwater along its face, and thus prevent scouring. It also varies in length, according to circumstances. At the outer end of the wing-dam is the slant, extending down-stream with the current, its length depending upon the locality; it can readily be extended at any time should the occasion arise. It had better be too short than too long, as it is easier to extend than to remove a part of it. At the elbow formed by the wing-dam and slant a short spur is projected up stream, making equal angles with both.

The spur receives the force of the current and protects the slant; the latter hold the water away from the lower side of the dam until the current becomes comparatively slow, when it passes around the foot of the slant and returns, running up-stream, as it were, and deposits sand behind the wing-dam. Were it not for the slant and spur the water would pass around the end of the wing-dam in a long curve and meet the greater body of water some distance below, and, instead of depositing any sand behind the dam, the river-bed would wash out deeper, and the result would be a bad "crossing," (a "crossing" is where the main draught of water crosses from one bank to the other; it is "long" or "short," depending upon the distance required to make it.)

Slants and spurs are not only serviceable locally, but their influence extends much farther down-stream than would the influence of a dam without them. Therefore, they admit of the dams being placed farther apart, and as they are very short, compared with the lengths of dams, it is obvious that it is economical to build them. An examination of the map of the improvement of the Vistula (a European river) proves this, for here we find dams with neither slants nor spurs very close together, *i. e.*, once or twice the length of a local dam apart, depending upon the shape of the shore-line, concave or convex.

7.—LOCATION OF DAMS.

The location of dams should be attended with great care, as the nature of the river and banks changes more or less continually. All the component parts which are to assist in producing the desired results, or which may withhold them, must be considered. It is best to keep the channel in the middle of the river, away from the shore, when the banks are bad. By avoiding unnecessary crossings one dam will protect another. In Fig. 7, suppose A to be a portion of the current which strikes the dam B along the wing-dam. A portion of its force is expended, but at the point B it is accelerated, there being an eddy just below this point, owing to the head of water produced by the wing-dam. At B′ it again loses a portion of its force and spreads over the entire area between the dams and the shore, gradually losing its force, so that the wing-dam at C is relieved by the dam above. The same will take place at C as at B, and so on. Fig. 8 represents a long wing-dam, which holds the water against a gravel-bank; a closing-dam, which connects an island with the main shore; and a series of shorter dams, which keep the channel away from either shore. Sand is represented as deposited before and behind the dams; it is deposited behind them in horseshoe bars, due to the spreading current. Closing-dams should never be constructed from the shore directly to an island, unless the latter have a good bank at the head, (which does not obtain on the Wisconsin River,) in which case a shore-protection will be required at each end of the dam, there being, of course, no necessity of a slant and spur. When the bank is poor, the dam should be so placed as to protect the head of the island. All rivers differ somewhat; there is no general system which can be entirely adopted; hence constant observation, experience, and study *only* can fit one to locate dams.

8.—MANAGEMENT OF BOATS.

The two construction-crews are engaged on separate dams in juxtaposition. It rarely happens that a dam must be built in very deep water except to cross an occasional pocket. Where the water is deep enough to float a loaded scow broadside along the site of a dam that has been staked out, it requires the utmost caution and skill to maintain it in such a position without the aid of a steamer, (sometimes required,) especially after the dam is well under way and the current thereby accelerated. Much time is therefore saved by a good knowledge of boating on the part of each member of the construction-crew. It generally happens that a shore-line can be put out from one or both capstans; should it be so that but one can be used, the other may be fastend to an anchor placed several hundred feet above the scow. (Pieces of boiler-iron 9 inches by 18 inches, riveted to the flukes, give additional resistance in sand.)

In dropping a scow into position for work, always keep one end a little above the other, so that the broadside of the scow will make an angle of forty-five degrees with the line of the proposed dam. When the lower end comes into position drop the grouser of that end, allow the other end to swing down into place, drop its grouser, and then wind up the slack of both lines. It is always preferable to be a little above the desired position at first, for the scow will necessarily drop down a little as the lines become taut, and also as the grouser will give away a little. To move a scow along the line of a dam, raise the grouser nearest the next position for work, wind up on the corresponding line enough to bring the scow quartering with the current, then raise the other grouser, wind up or slack away the corresponding line as the scow approaches or recedes from the dam; the scow will then move in the desired direction, (unless the anchor-lines make too great an angle at their prolonged intersection.) As soon as the lower end comes into position, drop its grouser, and proceed as before. The anchor and lines are shifted from time to time, if the dam be a long one. In building the slant or shore-protection, one anchor and the grousers will retain a scow in position, as its broadside is parallel with the current. Where the current is not very strong, the construction-crew can move the scows with poles, relying solely on the grousers to hold them in place.

The stone-scow is invariably lashed to the mat-scow, and is always between it and the dam or shore-protection to be built.

The loaded scows should be left by the tow-boat just above the site of the proposed work, so that the construction-crew may always have materials convenient. The quarter-boats are placed nearest the brushmen, as the other smaller crews can generally be taken to them by the tow-boat or by small boats. Every change of location presents difficulties to be encountered, such as strong or cross currents, heavy winds, deep or shoal water to operate in, &c. Practice and experience alone can surmount these obstacles. The overseer should, therefore, have at hand every means possible to meet an obstacle as soon as presented, in order that no time may be lost.

9.—FELLING LEANING TIMBER AND SNAGGING.

When materials are so convenient to the work as not to require the full time of the tow-boat, she can assist in felling leaning timber, when necessary, or in snagging. (Wherever practicable in winter, leaning timber should be felled upon the ice.) Snagging should keep pace with the improvement. For these purposes a crew of 12 men, including boat-hands, are about as many as can be employed to advantage. The boat-crew sees to the boat, &c., and the balance serve as ax-men. Many trees can be felled on the bank, but when a tree leans very much over the bank, it is pulled onto the bank, while it is being cut close to the butt, by means of a rope fastened near the top of it, running back thence to a snatch-block, and thence to the sheaves and spool on the boat. Snags are pulled in a similar manner, except they be small, when a direct line from the spool is used. Timber and snags are trimmed and cut up into short lengths when on the bank, so that they will not again obstruct navigation if carried off by high water.

10.—CONSTRUCTION OF SHORE-PROTECTIONS.

Shore-protections are built as follows, (Fig. 9:) The bank is cleared of flood-wood, &c., and is then sloped off to an angle of about 45° with the surface of the water. The loaded scows are then placed in position broadside to the bank at the lower end, and about 15 feet from the shore. The mats are placed one at a time, butts down stream; those under water are sunk as follows: A mat is thrown overboard by the four carriers, and as soon as it touches the water the mat-poles are thrust through it (Fig. 10) on the down-stream side of the binding-poles, by the men standing on the scow; if its position be not exactly right, it can be moved about on the surface of the water by means of the mat-poles, care being taken, where the current is strong, that one pole is fast while the other is changing it. The mat-hook is used to hold the mat (as shown in Fig. 10) where the current is very strong. The mat is so placed that it will easily slide down the mat-pole into place when loaded. The up-stream end is loaded first. The first course is carried up to high-water mark; 2 or 3 mats are placed under low-water mark; these are completely covered with stone; those above are covered only over the brush-ends as far as the brush-binders. The second course is laid in a similar manner, just lapping the up-stream binders of the preceding course, and so on up to the proposed wing-dam, so that the shore will be virtually shingled with mats. The stone is thus protected from ice, rafts, and drift-wood by the mats. The same method is effectually used to protect sandy banks that are prone to wash away. In some localities, short dams without slant or spur serve to protect banks.

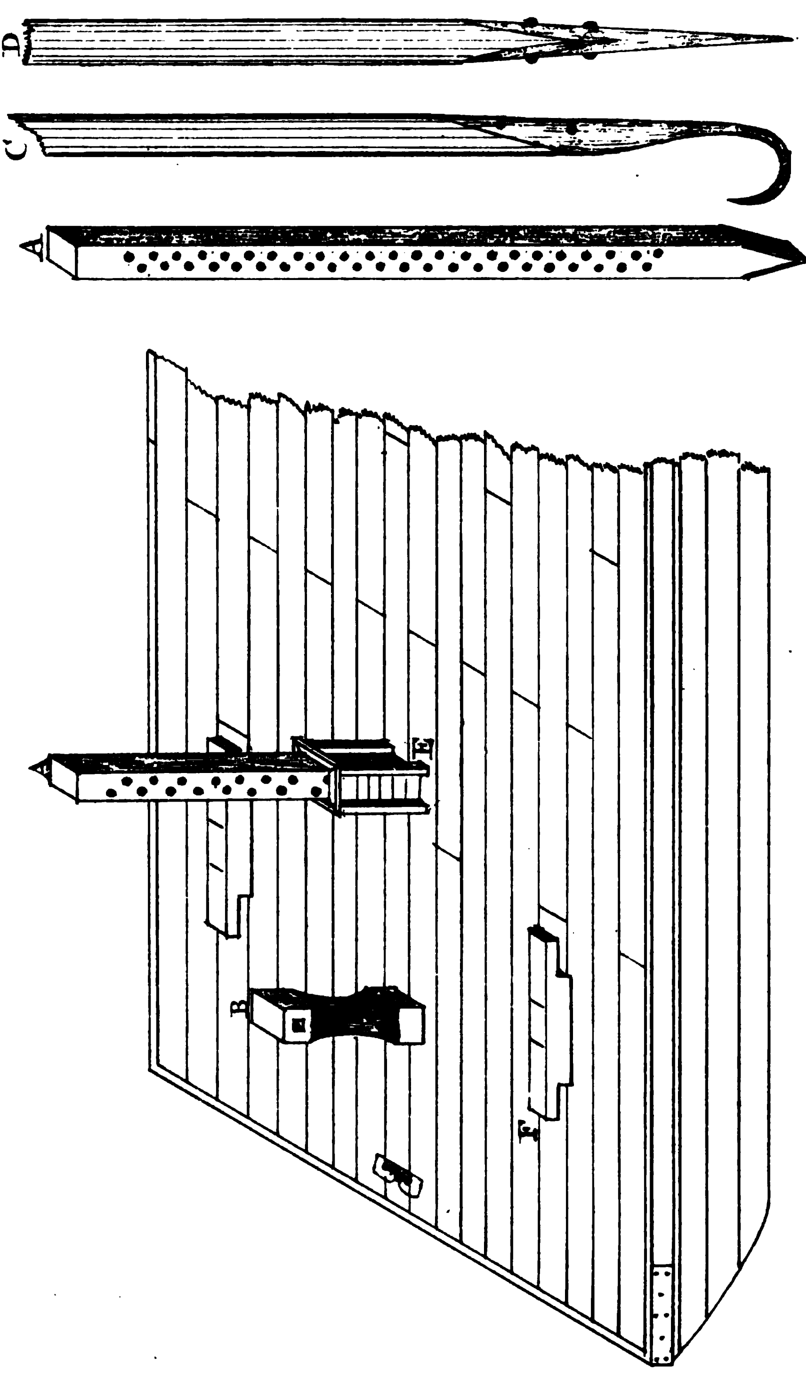
11.—CONSTRUCTION OF SLANT AND SPUR.

The slant is next built, work being commenced at its lower end. The brush-ends of the mats are toward the channel, and all mats break joints. The first course of mats is laid its entire length and completely covered with stone. The succeeding courses are covered with stone only where lapped by the following course: The second course laps the brush-end binders of the first course; the third laps the second one-half; the fourth laps the third two-thirds; and from this, the dam is raised by adding succeeding courses, covering each other very nearly. The face-mat is laid last to check scouring along the channel side of the slant. The end of the slant is in steps, (Fig. 11.) The spur is next built in a similar manner; at the end of it is a layer of mats well covered with stone.

12.—CONSTRUCTION OF WING-DAM.

The wing-dam is built last of all. It is carried up in a manner similar to the slant, except that each course is built its entire length before commencing the succeeding; and, also, should the bottom be uneven, it is leveled up in order to avoid a rush of water at any one place. The shore-end is faced with fine stone or gravel to prevent any leakage that might cause the dam to settle at this point. The apron (or first few

Fig. 1.



A. *Grouser.*—B. *Capstan.*—C. *Mat-Hook.*—D. *Mat-pole.*—E. *Grouser-frame.*—F. *Cleat.*

Fig. 2.

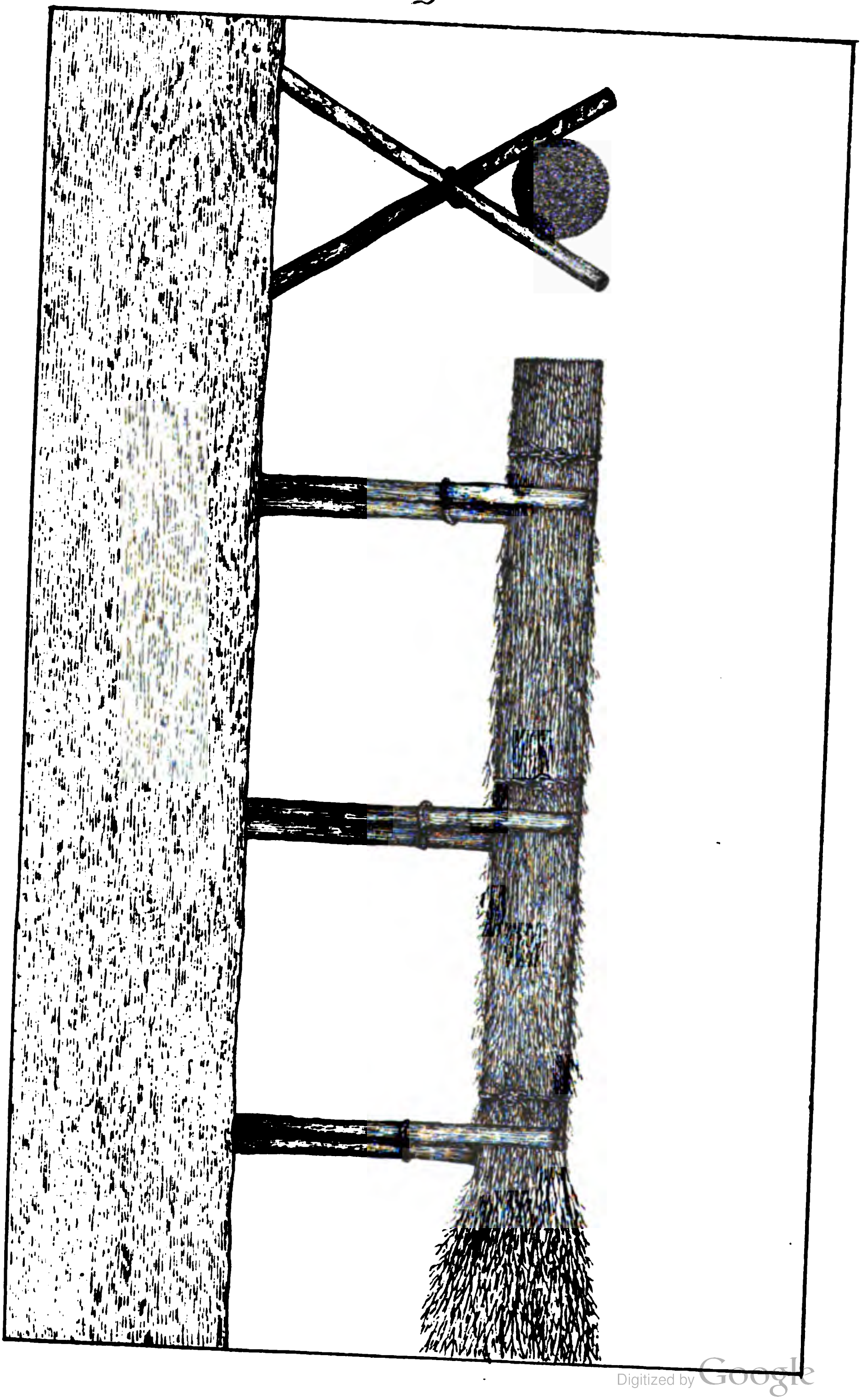
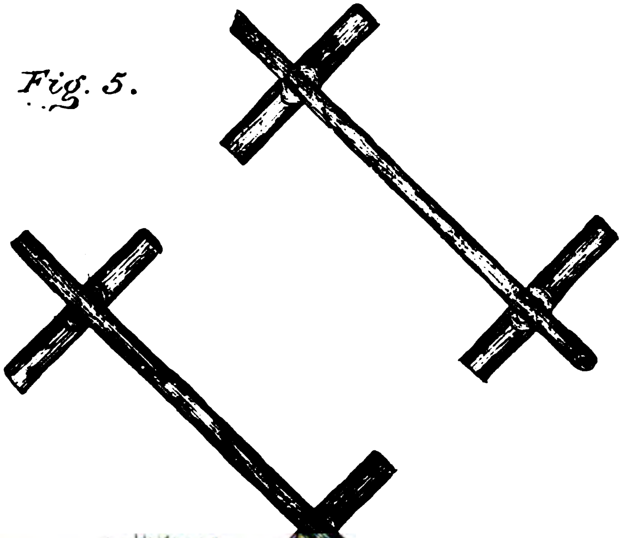


Fig. 5.



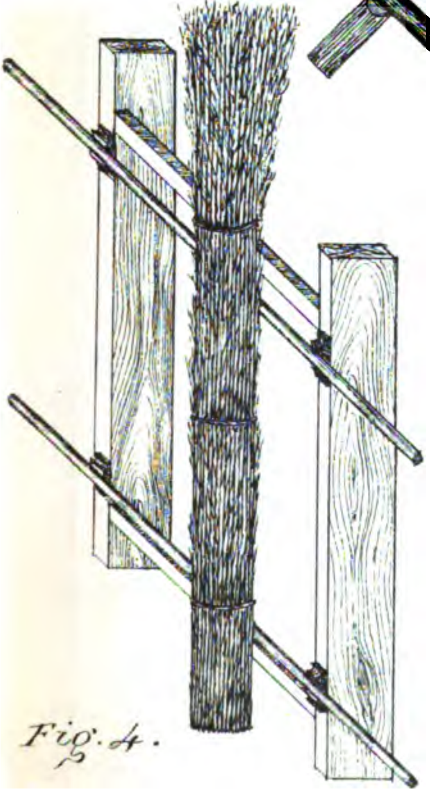


Fig. 4.

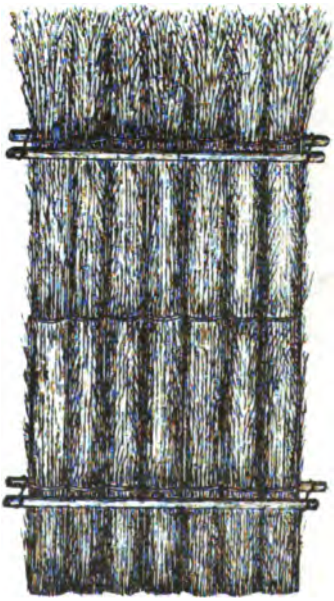


Fig. 3.

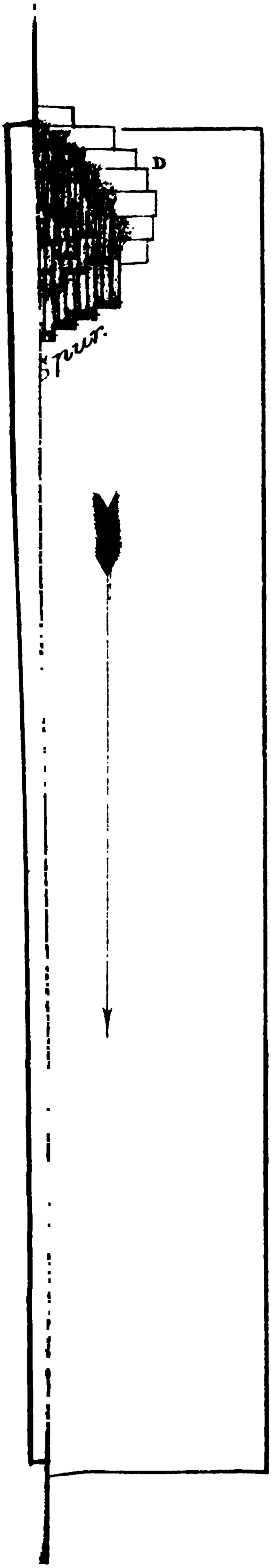

D
Spur.

Fig. 7.

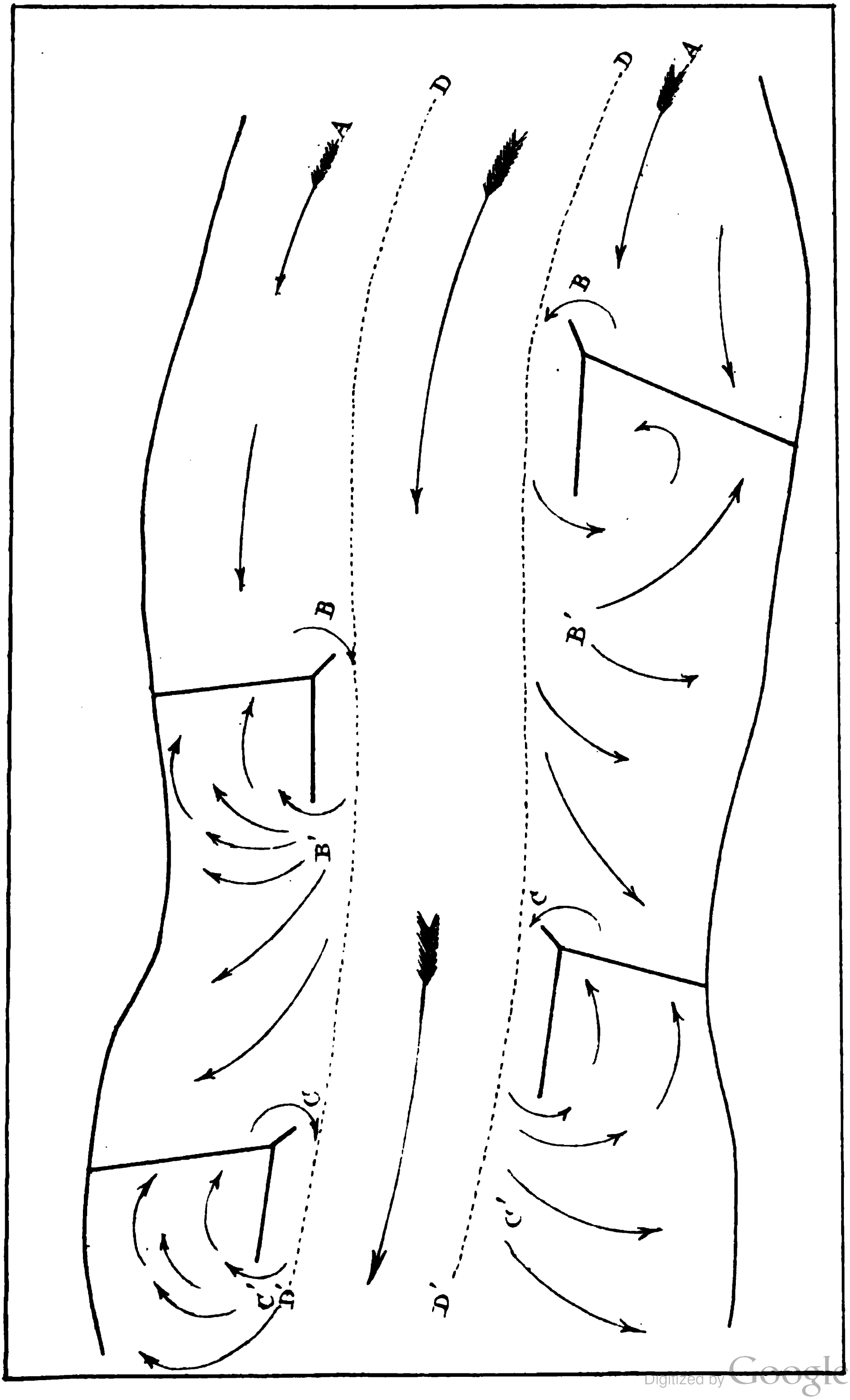
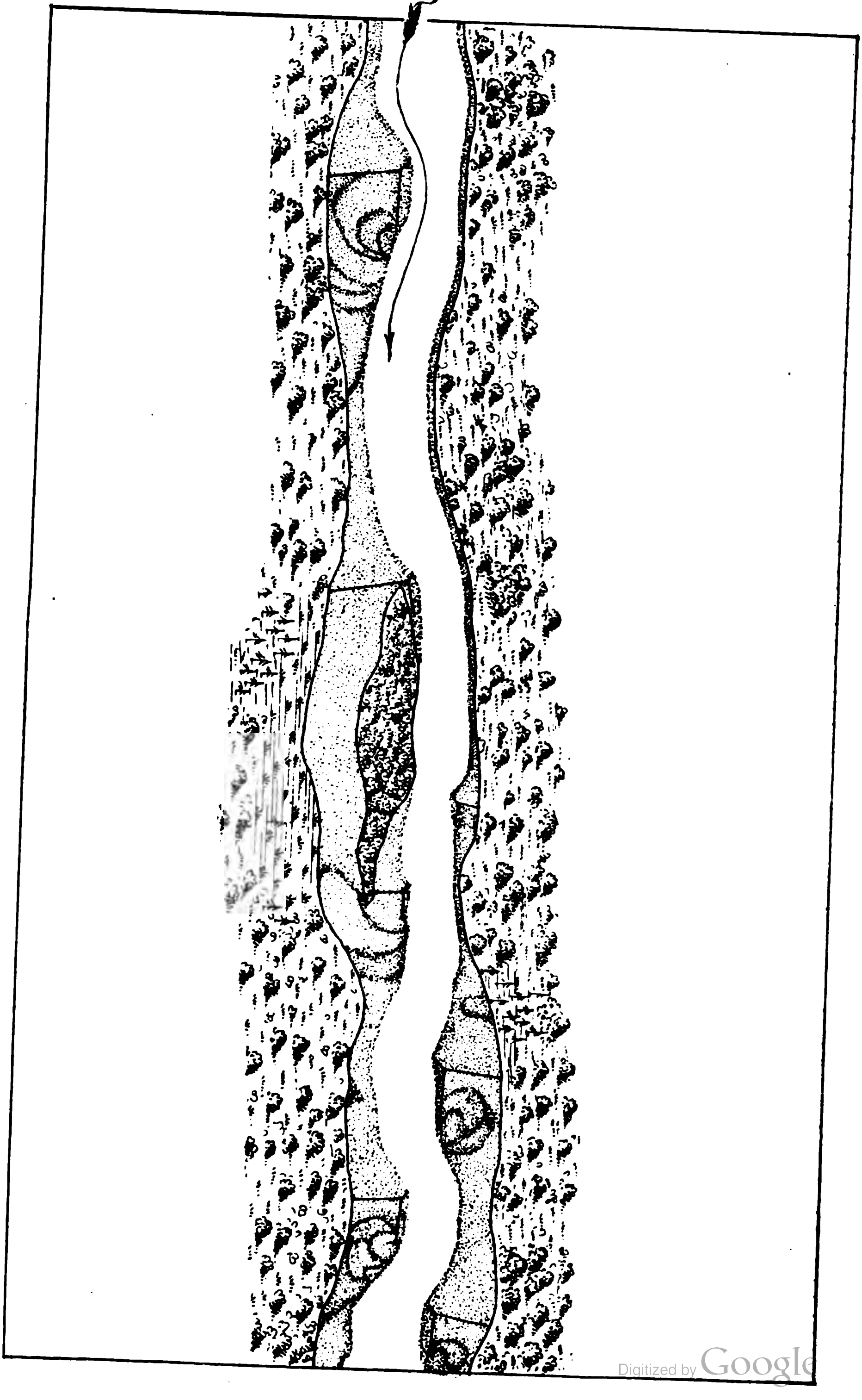
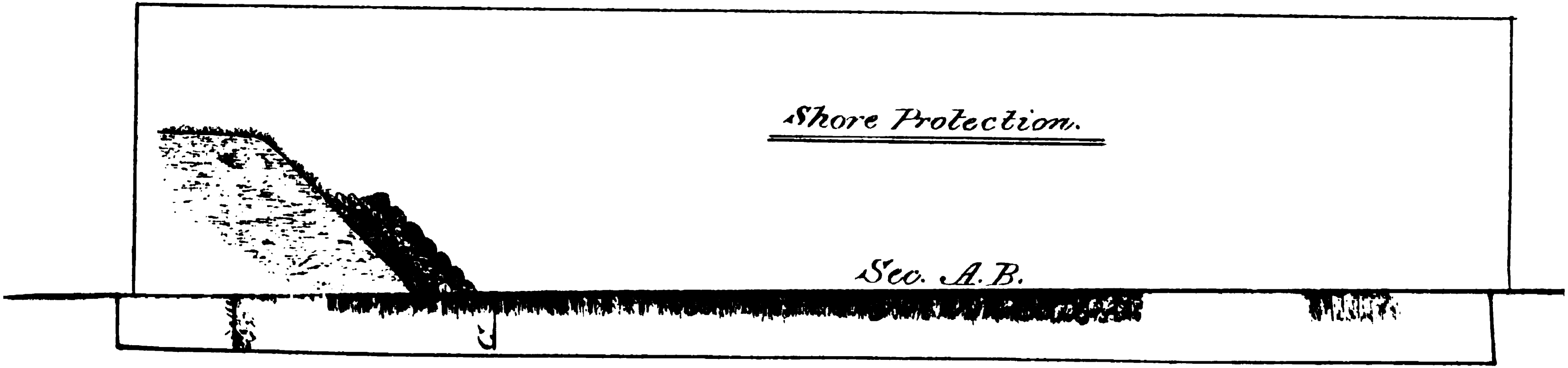


Fig. 8.





Shore Protection.

Fig: 10.

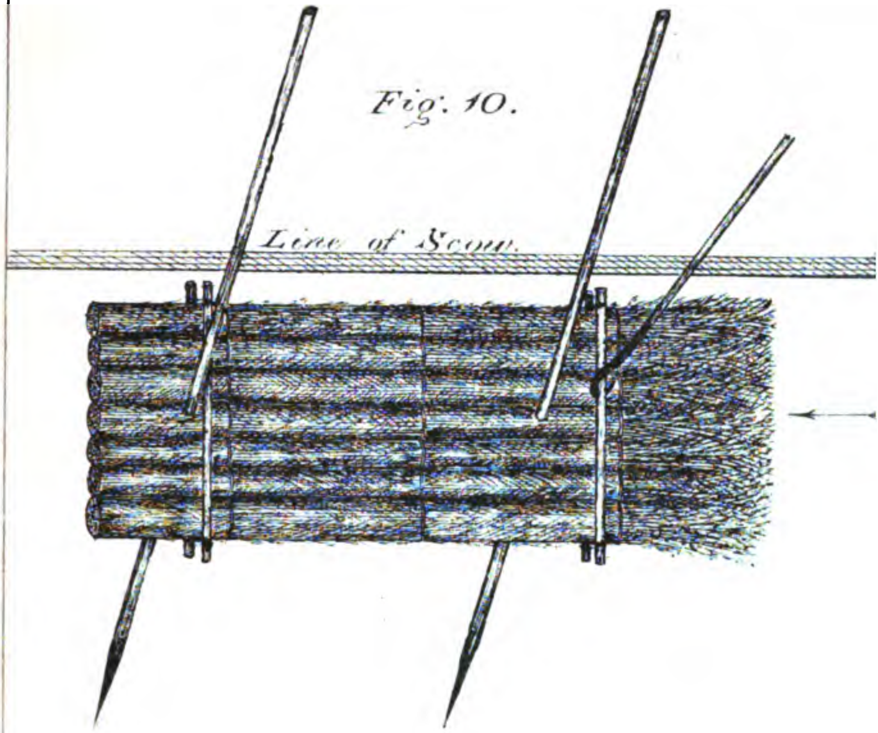


Fig: 11.

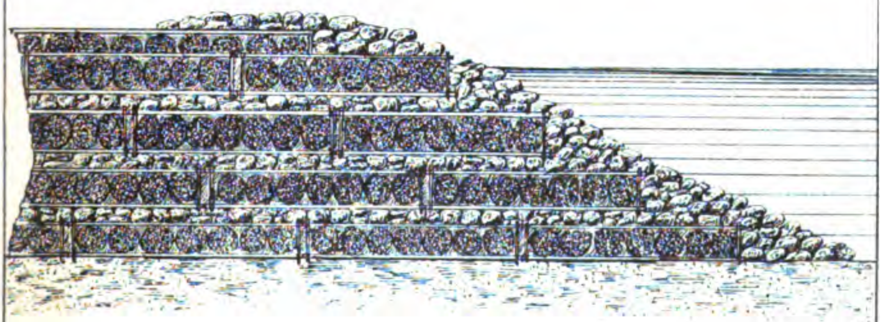
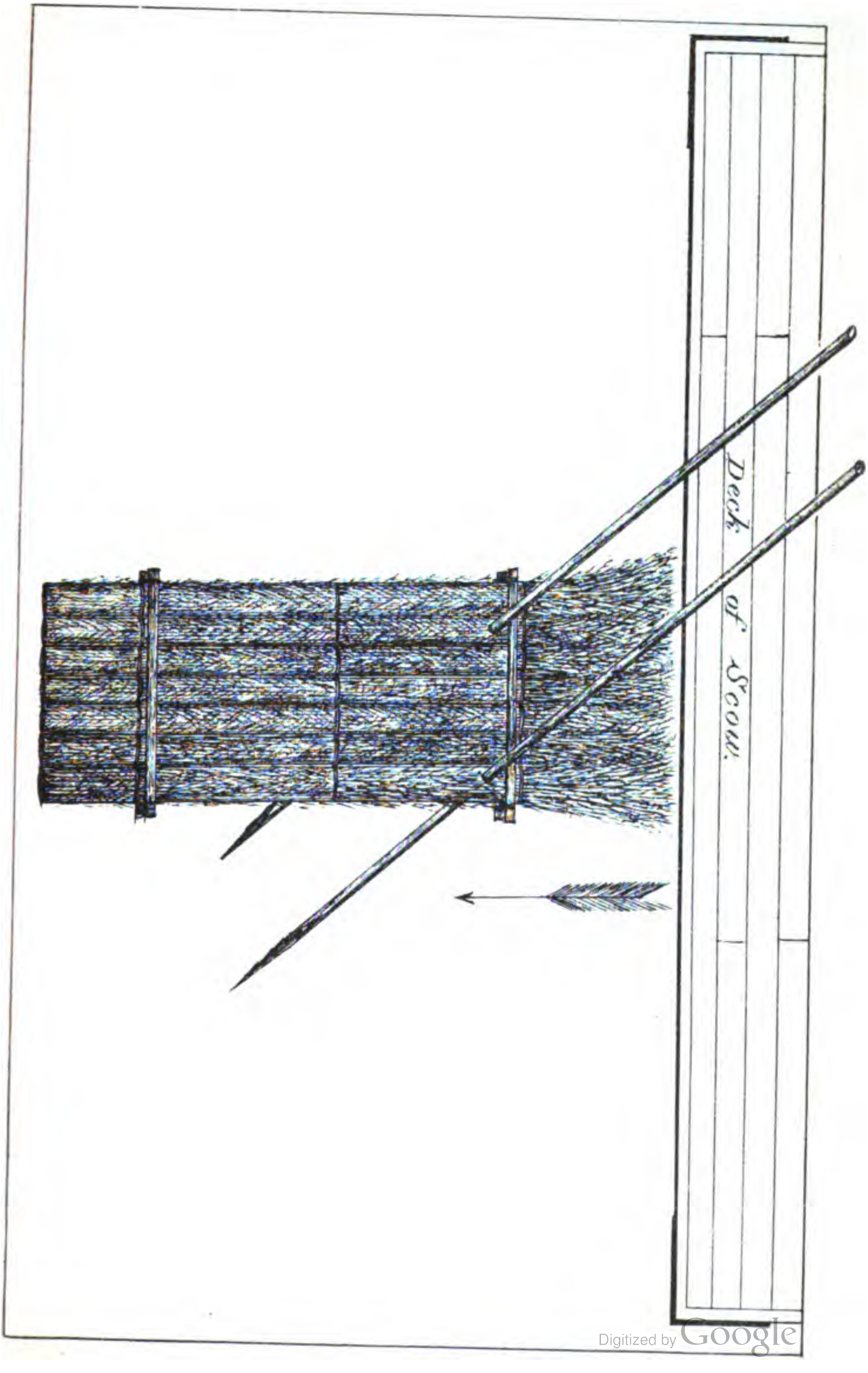


Fig. 12.



courses) receives the water falling over the dam in high water and thereby checks the undermining that would otherwise occur, and thus prevents settling to a great extent. Stone are not shown on the plan of the wing-dam, (Fig. 6,) the object being to show the relative positions of the mats in courses. In the cross-section F, (Fig. 6,) stone is shown between mats The stone-scow being in position with a mat-scow alongside, above, four men bring a mat to the lower side of the stone-scow; two lines, ½ inch diameter and 20 feet long each, are passed around the upper brush-end binder just inside the two outside strands of marlin, with one man at each line; the mat is thrown into the water by the carriers, butt down stream. The object of these lines is to hold the mat on the *surface* of the water until sufficiently loaded with stone, otherwise the mat sinks before stone enough have been placed on it, and many stone are wasted in attempting to throw them on the mat when sunk. These lines are easily removed after the mat has sunk, by letting go one end and pulling on the other end. Two more lines are necessary, so that while one set is in use the other may be similarly arranged on the next mat to be sunk. After the mat is thrown into the water, two poles (Fig. 12) are passed through the mat immediately in front of the binder and near each of the lines. These poles are stuck in the sand, and a sufficient slant is given them so that the mat will in sinking slide down on them into place. A third pole is placed at the edge of the last mat sunk, to prevent the next from lapping it. Two mat-hooks are caught in the up-stream binder; stone is thrown on carefully, first in the middle, then on each side of the up-stream binder, and then on the brush-end of the mat; and when sufficiently loaded the men holding the hooks and lines *must let go together* and the mat will slide down on the poles into position. By this method mats are sunk in very swift or deep water. If there be a cross-current, commence sinking mats so as to work with it; the water will then help to force the mats close together. In many cases neither lines nor hooks are necessary; much depends on the depth of water and the swiftness of the current.

The two construction-crews should sink an average of 250 mats in 8 hours.

III.—LOWERING THE DAMS AT THE OUTLETS OF LAKE WINNEBAGO.*

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., May 1, 1876.

GENERAL: I have the honor to submit the following report in regard to lowering the dams at the outlets of Lake Winnebago, Wisconsin, known as the Neenah and Menasha channels, called for by your letter of the 27th ultimo. This report is to be taken in connection with my letter of the 21st ultimo, calling attention to the "act to aid in the improvement of the Fox and Wisconsin Rivers," approved March 3, 1875.

Under this act the process of ascertaining the amount of compensation for flowage damages arising from these dams is made contingent upon the "*opinion* of the officer in charge that it is not prudent that the dam or dams be lowered;" and it would seem that the first thing to do would be to ascertain this opinion. The attorney appointed to represent the interests of the United States under this act had a different opinion, and seemed to assume that because the dams were not lowered, therefore it was the opinion of the officer in charge that they should not be lowered. Consequently the United States has been to considerable expense in expenses incurred by said attorney and in surveys deemed necessary by him to protect the interests of the United States.

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* The letter of the Chief of Engineers to the Secretary of War on this subject, dated May 8, 1876, may be found at the end of this appendix, (X.)

Under the laws of the State of Wisconsin, made applicable by the act above mentioned, persons having claims for flowage may apply to the judge of the circuit court of the State, setting forth their claims, and the judge may appoint three commissioners to decide on the amount of compensation due. This has been done in a great many cases, and awards have already been made, I am informed, to about $70,000. This, I am reliably informed, is but a small portion of these claims which will have to be paid if it is ultimately decided that the Government is liable. The commissioners appointed by the judge, whose compensation was fixed by him at $10 per day, sent me their bills for payment. I referred them to the attorney for the Government for his opinion, stating that I did not think the Government should pay them until it should be decided that the Government was liable for damages; that these commissioners were not appointed at the instance of the United States; and that a person having a claim not valid might have commissioners appointed, for whose payment the Government would be liable; and that the door was thus open for a large and indefinite expenditure.

Mr. C. R. Gill, the attorney for the Government, reserved his opinion, although he seemed to think that the Government would ultimately pay these commissioners, and I understand that a bill has been introduced in the United States Senate directing said payment.

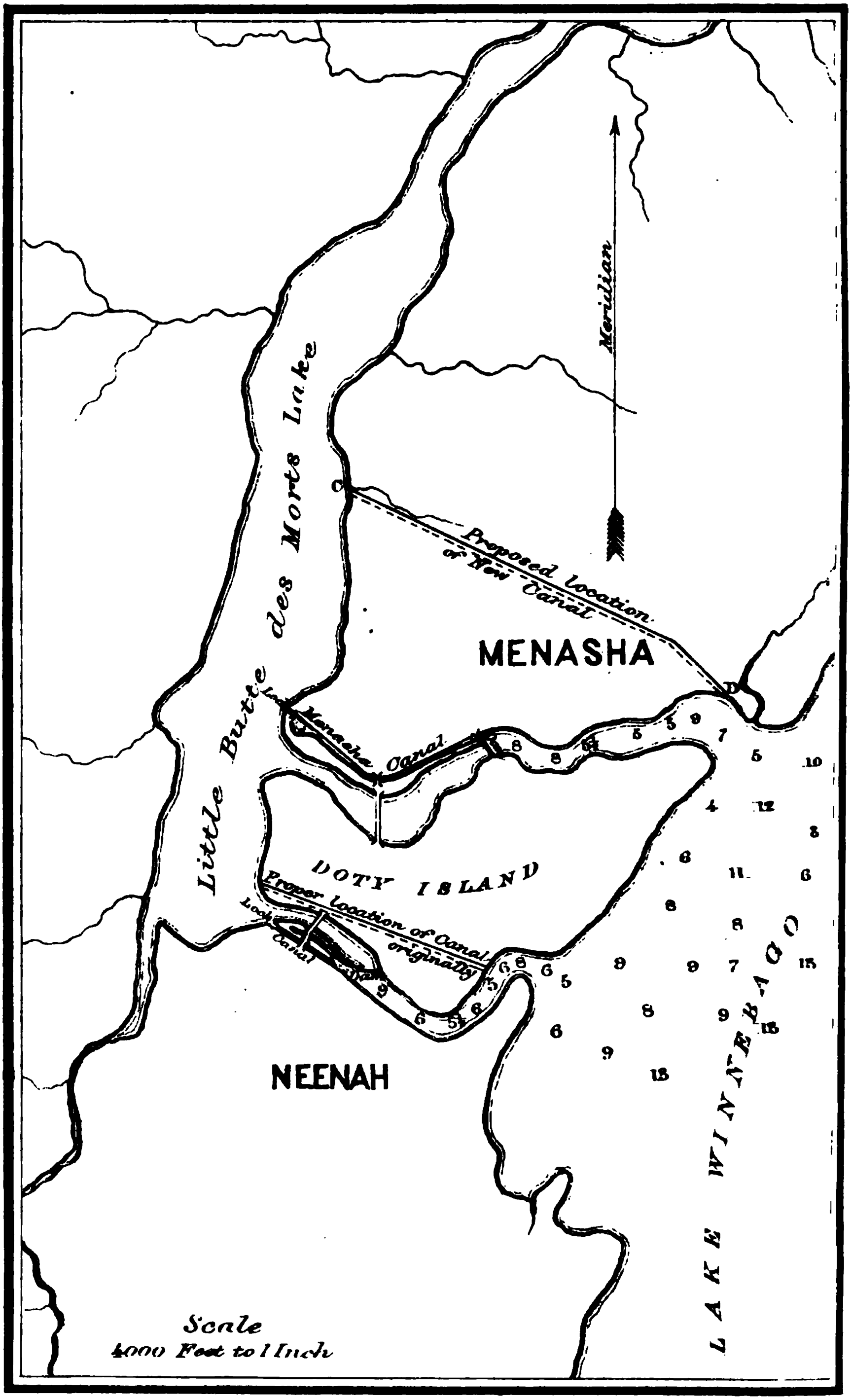
In view of these facts it has seemed to me that the question of lowering the dams should now be considered. If, in the opinion of the officer in charge, it is prudent that these dams be lowered, the United States would be relieved from further expenses under this act, so far as these particular dams are concerned. I understand, as a matter of course, that this opinion is to be given solely in reference to the matter of navigation, which is all that the Government has to do with it.

These dams were originally built by private parties for manufacturing purposes. Had it been simply a question of navigation, no dams would have been necessary.

According to the original survey of Captain Cram, topographical engineer, in 1839, the height of Lake Winnebago above Little Lake Butte des Morts was 7½ feet. These lakes were connected by channels, known as the Neenah and Menasha channels, (tracing inclosed.)

It was not necessary to raise the level of Lake Winnebago for purposes of navigation. A canal on the right bank of the Neenah outlet, marked by the dotted red line A B, with a lock of 7½ feet lift, was all that was required; nor is anything more necessary now, but this route is impracticable at present, on account of increase in value of property, the ground being occupied. It was important to the water-power interests to obtain an increased head of water, and accordingly dams were constructed on both outlets for water-power purposes, thus raising the water-level, causing flowage, for which those interested ought to pay.

I have been unable to ascertain the full history of these matters, but for the purpose of this report it is sufficient to state that when the State undertook the improvement of the Lower Fox for purposes of navigation, it made some arrangements with the owners of the dam at Menasha as a part of the route, retained the dam at its present height, and thus, by some legal decision, became liable for the flowage caused by the dams; which legacy it has bequeathed to its successors, the Fox


Meridian
Proposed location of New Canal
C
D
MENASHA
Little Butte des Morts Lake
Lock
Menasha Canal
DOTY ISLAND
Proper location of Canal originally
Lock
Canal
Dam
NEENAH
LAKE WINNEBAGO
Scale
4000 Feet to 1 Inch

River Improvement Company, the Green Bay and Mississippi Canal Company, and, at last, to the Government of the United States.

There have been suits pending for many years for damages resulting from this flowage. When the dams were built the value of these lands was very small. The matter might have been settled then at comparatively small cost. But it was the manufacturing interests created by these dams, and the opening of navigation on the Fox River before the time of railroads, that developed that region, building up towns, and greatly enhancing the value of property. It is extremely doubtful whether any of these claimants could show any actual loss from flowage, on account of the increased value of property, due, in a great measure, to these very dams. The damage to various interests which would be caused by the lowering of these dams *now* is vastly greater than the damage by flowage *then*, and these damages appear to be awarded on the present value of property, as near as I can ascertain.

In regard to the lowering of the dams, while so far as navigation is concerned they can be lowered and even dispensed with, as a practical question they will not be lowered, as the interests of the two thriving manufacturing towns of Neenah and Menasha, and other interests, are too great to permit it. But I see no reason why the Government should be made to pay all these claims arising from works not necessary for purposes of navigation, and, after much consideration of the question, I am of the opinion that it is prudent that the dams be lowered, so far as the Government is concerned; and as a practical solution of this matter which will relieve the Government, I would propose to deepen the present canal to such a depth that if the dams were removed, there would be sufficient depth for navigation; or, what is better, cut a new canal to the same depth. This latter plan would relieve us from all conflict with the water-powers which are now taken from the canal, and as the dams would not be necessary for purposes of navigation, the flowage damages would fall upon the manufacturing and other interests involved in maintaining them, and I am inclined to the opinion that the question of flowage damages would then be settled at a much smaller cost than by the process now being pursued; or if the United States is to be held liable in any event, in case the dams are kept up, I would say remove them and deepen the canal, or make a new one.

I have had surveys made by various routes for a canal to secure the object in view. The estimated cost of the first, and, in my judgment, the best route, marked "C D," in full red lines, is as follows:

For a canal 75 feet wide and 8½ feet deep, which would give a depth of 6 feet in case the dams were removed. Length of canal, 8,033 feet; mean depth of excavation, 18 feet:

For 37 acres of land, at $50	$1,850 00
For 112,462 yards of rock-excavation, at 50 cents	56,231 00
For 337,385 yards of earth-excavation, at 20 cents	67,477 00
Cost of lock	35,000 00
Cost of dredging 30,000 cubic yards to navigable water in Lake Winnebago, at 20 cents	6,000 00
Deduct from this the cost of lock, which will have to be built any way, *i. e.*, present lock rebuilt, and $25,000 for rock which will be needed for various purposes, reduce this estimate to	106,558 00

Which will cover the additional cost of new route over the present plan.

The amount which will be awarded for flowage will be much greater than this; some place it as high as $1,000,000. Moreover, by this plan we avoid all trouble with the mills at Neenah and Menasha. Lake Winnebago is the reservoir which regulates the amount of water in the Lower Fox.

The use of water by the mills interrupts the uniform discharge of water and interferes with navigation. I am inclined to the opinion that the mere announcement that it is the intention of the Government to make this canal will have a good effect.

This idea of making a canal without reference to the dams is not a new one. I am reliably informed that Governor Seymour, of New York, who formerly took a deep interest in this work and contributed greatly to its advancement, advocated this plan, though I believe no surveys or estimates were ever made.

The plan of Captain Cram contemplated no dams. His plan was a canal starting from Lake Winnebago and striking the river some miles below, but this involved a summit-level, which is now at all events impracticable, as there is not sufficient supply of water.

As an original question, no engineer would ever think of raising the level of a lake 30 miles long and 12 miles wide, and unnecessarily overflowing an unknown quantity of land. The entire western and southern shore of the lake is low land more or less flowed. As near as we can make out, the low-water level of the lake has been raised by these dams about 2 feet. This will give some idea of the amount of damage to be expected. Not only this, but the low lands on the Fox above Oshkosh are also affected.

In view of all this, I would respectfully recommend the canal above described, which will render the dams unnecessary for purposes of navigation, and relieve the Government from liability. There are lands flooded by other dams built by the old improvement company, but these seem to be necessary for purposes of navigation. Now, when the Government is expending large amounts of money for the direct benefit of this section, it seems unjust that it should be called upon to pay claims caused by works constructed 20 years ago, when the lands overflowed were of comparatively small value, and when the Government was in no way responsible for the works, which were unnecessary for purposes of navigation, and constructed exclusively for private purposes.

I am, general, very respectfully, your obedient servant,

D. C. HOUSTON,
Major of Engineers, U. S. A.

Brig. Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.

FOX RIVER.

IV.—REPORT OF CAPTAIN G. J. LYDECKER, CORPS OF ENGINEERS.

MILWAUKEE, WIS., *July* 5, 1876.

SIR: The following report of operations on the improvement of the Fox River, Wisconsin, for the fiscal year ending June 30, 1876, is respectfully submitted:

1. PORTAGE CANAL.

The work of widening, deepening, and revetting the canal connecting the Fox and Wisconsin Rivers, commenced the preceding year, was continued until December 4, 1875, when operations were suspended for the winter. During the course of this year's operations it became necessary to modify the plan of revetment on which we had started, on account of high banks and contracted space along the upper section of the canal, and for the same reason to haul the earth excavated in deepening the canal sometimes a distance of 1,200 feet or more, whereas it had been deposited on the canal-banks until that time. Though these changes caused some delays, the work was nearly completed when operations were suspended, and before they were resumed I was relieved (February 21, 1876) from the charge of this and all works on the Upper

Fox, above Lake Buffalo. Up to the time at which the transfer took place there had been excavated from the canal 119,802 cubic yards of sand, and a little over 19,000 linear feet of revetment had been built, leaving about 2,500 linear feet revetment and about 15,000 cubic yards excavation to complete the work. The two systems of revetment used in this work are illustrated in Plate V of sketches transmitted herewith.

2. FORT WINNEBAGO LOCK.

Four new gates were hung and planked; the planking of lock-walls finished from the point where work had been suspended during the fall of 1874.

The methods adopted for hanging these gates, being different from those usually followed, are illustrated in Plate III (*b*) of accompanying sketches; as these methods are explained in the description of plates, I will only say here that the system shown in figures I (*a*) and 2 (*a*) has proved to be the better so far.

3. GRAND RIVER LOCK.

The contract for building a new cut-stone lock at this place was awarded to C. C. Barker & Son July 2, 1875. It was annulled September 27, for failure to prosecute the work with proper energy. At that time only 1,714 cubic yards had been excavated from the lock-pit. The work was resumed October 8, the excavation (9,427 cubic yards) completed January 15, and, working through the winter, the pile and timber foundations were finished by March 4. Since then nothing has been done, except to deliver the necessary materials for the work; operations will be resumed as soon as practicable.

The lock-site was still under water at the end of the year. It is expected to have the work finished by the end of August.

4. PRINCETON LOCK.

The contract for this lock was also awarded to C. C. Barker & Son, July 2, annulled September 27, at which time 2,180 cubic yards had been excavated from the lock-pit. Work being resumed, the excavation (8,051 cubic yards) was completed by December 11; pile and timber foundations in by January 29, when operations were suspended until May 25. The pit was then pumped out and the work of placing concrete for foundations commenced; but the river rising suddenly broke away the embankment and flooded the pit June 16. The damage has since been repaired, foundations completed, and everything is in readiness to proceed with the masonry of lock-walls. The work will probably be completed by the middle of August.

5. WHITE RIVER LOCK.

Another of the works awarded to C. C. Barker & Son July 2; contract annulled September 27; 3,594 cubic yards excavated from pit. Operations resumed October 18, and the excavation (12,705 cubic yards) completed January 15; timber-work and foundations completed April 1; concrete and foundations placed April 29 to May 15, and all the masonry of lock-walls laid between May 19 and June 21. To complete the work requires the construction of dry-stone wing-walls at head and foot of lock, and the hanging of gates, valves, &c., all of which will probably be completed by July 20. For the foundations, 513 bearing-piles, 100,000 feet, board-measure, pine timber, 48,000 feet, board-measure, pine plank, and 210 cubic yards concrete, were used. In the lock-walls there are 1,653.8 cubic yards masonry.

6. BERLIN LOCK.

This work was also awarded to C. C. Barker & Son, July 2, and though he had made better progress on it than on any of the others, the absence of any visible preparations, or means for carrying on the work with energy, led to the annulment of his contract September 27, at which time the excavation of the lock-pit had been finished. The timber-work of foundations was subsequently put in and operations suspended December 16; since then nothing has been done besides delivering a portion of the stone required for the work. It is not proposed to go on with this work during the present season, unless the appropriation should be ample for other more important works.

7. EUREKA LOCK.

This work has been carried on from the beginning by day-labor. During the early part of the year the lock-pit was excavated by dredging; after the pit was pumped out it was found necessary to sheet-pile it on almost all sides before driving any bearing-piles or doing anything toward building the foundations. These were not completed until the end of October. Operations were suspended November 20, resumed May 1, and at the end of the year all the masonry works had been completed. To put the lock in working order it is only necessary to hang the gates and valves.

In connection with this work a canal, about 1,200 feet long, 100 feet wide, and 6 feet deep, was excavated during last summer to within about 90 feet of the lock-pit. The mass of earth left is now being removed, and it is expected to have everything finished about the lock and canal before the end of July.

8. APPLETON (2D) LOCK.

A contract for tearing out the old lock, and building in its place one of cut stone was awarded to L. J. and J. Day and T. W. Call, August 10, 1875. They worked along slowly until November 20, when their creditors having seized upon all their tools, &c., they abandoned the work. Up to that time they had accomplished nothing beyond tearing out the old lock. After this, they were not seen on any of their works along the Lower Fox, and finally (February 8, 1876) their contract was annulled. At this time no arrangements had been made for supplying the stone required for building the lock as designed, and in order to avoid much delay beyond the date originally set for completing the work, and to make the cost a minimum, it became necessary to abandon the idea of a lock with cut-stone face. Accordingly, when operations were commenced (April 24) by day's labor, it was determined to make the body of walls of concrete, with stone masses rammed in, and to face the walls with hammer-dressed stone in irregular courses, using for this purpose such stone as one man could handle, and which could be readily obtained in the vicinity.

The excavations for foundations of walls having been made April 24 to May 27, masonry-work was commenced May 16. At the close of the year the foundations (1,500 cubic yards concrete) had been completed, and 2½ feet in height of lock-walls built. It is expected to finish the work by the 1st of September.

9. LITTLE CHUTE (UPPER COMBINED) LOCK.

The contract for rebuilding this work was awarded to C. C. Barker & Son July 2 The contract was annulled September 27, at which time the old lock had been torn out, but no preparations had been made for going on with the work. Operations were resumed early in October, and the work of placing timber and concrete for foundations pushed ahead rapidly until December 4, when it became necessary to suspend during the winter. Operations were resumed May 2, and at the close of the year the lock-walls were built up about one-third of their height. It is expected to finish the work by the end of August.

10. THIRD AND FOURTH LOCKS, KAUKANA.

The contracts for rebuilding these two locks were awarded L. J. and J. Day and T. W. Call August 10. After having torn out the old works, they abandoned the job, (November 20,) became bankrupts, and the contracts were finally annulled February 8, 1876. For the purpose of obtaining stone, they were authorized to make use of the Grignon quarry, which adjoins the works, and is controlled by the United States for the benefit of the improvement; but up to the time they were compelled to suspend they had not taken out stone enough to build half of one of the locks. Operations were resumed on the fourth lock about the middle of June, and at the close of the year two courses of masonry had been laid, making the lock-walls 3½ feet high.

Nothing has been done on the third lock since operations were suspended last fall. It is expected to have both in working order by the middle of September.

11. KAUKANA DAM.

The building of a new crib-dam at Kaukana was commenced late in the fall of 1874; work was suspended during the following winter, and was not resumed until the middle of July, 1875. It was the original intention to bolt the bottom courses of timber to bed-rock; but, after about one-half the dam had been constructed in this way, the difficulties and delays in carrying it further necessitated a change of plan in order that the work might be completed before winter. Figs. 1, 2, 3, and 4, Plate I, of accompanying sketches, illustrate the original plan of dam, and Fig. 5 shows the change, in which the foundation-crib rested on the gravel overlying bed-rock, and was built up to the lower water-line. In spite of this change, the early date at which winter set in found the dam still unfinished, a portion about 120 feet long, near the middle, being left without sheathing. Through this part a large volume of water passed with a very swift current and brought floating masses of ice and drift against the dam with considerable force. Finally (December 6) the upper courses moved from the effect of these repeated blows, so as to give a curved outline to the crest of the dam, the versed sine of the curve being about 18 inches. Nevertheless, no further movement took place during the winter, nor until May 4, when, the river rising higher than ever known before at that place, the curved part of the dam was carried away.

It was not considered advisable to do anything toward repairing it until the river reaches its low stage. The dam is 596½ feet long; the length of section carried away is 123 feet.

12. CEDARS DAM.

Contract for building a new crib-dam, to replace the old structure, was awarded to L. J. & J. Day and T. W. Call, August 10. Operations were in progress from August 17 to November 20, when the contractors abandoned the work. Delays from waiting for materials were of frequent occurrence. At the time the work was abandoned the dam had been finished to the top of the sixth course from shore to shore, except for a length of about 150 feet, where the stone filling was placed only to the top of the second course. This left 6 feet in height of crib unsupported, and early in December this section was carried away. The contract was annulled February 1, 1876. Since then but little has been done toward completing the dam, on account of the difficulty and expense attending this character of work, if attempted during the time of high water. The length of the dam is 829 feet 10 inches, and the average height of its crest above bed-rock is 12 feet.

13. LITTLE CHUTE DAM.

This is another of the works awarded by contract to L. J. & J. Day and T. W. Call, August 10, 1875, and of which they completed about three-fourths of the dam, when they abandoned it, November 20. This contract was annulled February 1. Unlike their other dams, at the time they abandoned them, this one was well filled with stone, and quite secure against the action of freshets. On this account but little damage was done to it during the winter and spring. Since then the abutments have been completed. The dam is 13 feet high and 711 feet long. A length of little more than 500 feet has been finished; the remaining 200 feet will be built as soon as the river falls from its present high stage.

14. RAPID CROCHE DAM.

Still another of the works for which the contract was awarded to L. J. & J. Day and T. W. Call, August 10, 1875, and upon which they were engaged until November 20, when their lack of means forced them to throw it up. About one-third of the dam was then finished, but the crib was only partly filled with stone. At the north end a light board coffer-dam alone connected the dam with the canal-bank. When the river rose, January 1, this was carried away, and the water rushing through threatened the complete destruction of the canal-bank. With great difficulty the rush was stopped, and a new coffer-dam finally constructed. Their contract was annulled February 6, 1876. Since then work for completing the dam has been pushed ahead as well as practicable, considering the high water that has prevailed throughout the season. The total length of dam is 540 feet, of which there remains about 50 feet on which no work is done, and 200 feet that is only from 2 to 3 feet high.

15. THE LITTLE KAUKANA DAM.

This is the last of the works awarded to L. J. and J. Day and T. W. Call, by contract, August 10, 1875, and which they abandoned November 20. At this time all the piles had been driven; the upper row cut off and partly framed, but not connected in any way with the lower row. The sheet-piling had been placed, and most of the horizontal sheathing secured. In this way the water-surface was raised; but as no filling had been placed in the dam, and as there was no connection between the two rows of piles, the entire structure was badly damaged during the winter, the upper row of piles being forced over the entire length of dam and broken off for a distance of about 80 feet. The contract was annulled February 1, 1876. Since March 1, various attempts have been made to straighten up the dam and continue its construction, but with little success, owing to high water.

The total length of dam, when completed, will be 586½ feet. It differs from all the other dams on the Lower Fox, being a "pile-dam," the river-bed clay, or clay and gravel, while the others are crib-dams, and the river-bed rock. The details of its construction are shown in Plate II of accompanying sketches.

The details of crib-dams are shown in Plate I.

16. DREDGING UPPER FOX.

At the opening of the year, the two old dredges were at work cutting the Eureka Canal; about the middle of August the small dredge commenced working on the bars below the lock-site, the other remaining at work on the canal until the middle of September, when she was also moved to the bars below.

On the 16th of October, the small dredge commenced work on the Berlin Canal to facilitate the delivery of materials at the new lock-site, and continued to work there until November 17, when the river suddenly froze up. The total amount dredged during the season was about 60,000 cubic yards.

In order to facilitate the transportation of materials to the site of the Grand River lock, the small dredge was sent to dig channel-ways through the bars between Montello and Lake Apuckawa, about the middle of May, and worked until the middle of June. It then became necessary to stop working her on account of the bad condition of boiler and machinery.

A new dredge has been built since last winter, but at the close of the year was not quite ready for work.

17. SURVEY OF THE LOWER FOX.

During the months of October and November a survey of the Lower Fox was made extending from Menasha to De Pere, but omitting the rapids in the river, which were passed by canal, viz: at Appleton, Little Chute, and Kaukana, the line of survey at these places having followed the canals.

It is proposed to supply these omissions during the present year, when the maps which have been made will be forwarded.

18. MISCELLANEOUS.

A waste-weir was built through the canal-bank at Kaukana to facilitate the construction of the new dam at that place. Breaks occurred at several places in the canal-banks along the line during the past spring, the most important one being at Kaukana. Others were at De Pere, Appleton, Menasha, and Montello. Such repairs were made at the different points as sufficed to prevent any further immediate damage.

During the high water of spring freshets there was imminent danger of overflowing the levee on the south bank of the river opposite Kaukana; but a considerable force, working day and night, succeeded in raising it as fast as necessary, and thereby prevented any damage being done.

For building lock-gates a force was organized during the winter, and have built in the mean time all the gates required for the locks now under construction, in all thirty gates.

G. J. LYDECKER,
Captain of Engineers.

Maj. D. C. HOUSTON,
Corps of Engineers.

DESCRIPTION OF PLATES ACCOMPANYING REPORT OF OPERATIONS FOR THE YEAR ENDING JUNE 30, 1876.

PLATE I.

The general features of crib-dams, projected for replacing some of the old dams on the Lower Fox, are shown on this plate. They are designed only for rock bottoms, and are in course of construction at the Cedars, Little Chute, Kaukana, and Rapid Croche. When the bed-rock can be reached without great difficulty, the cross-section shown in Fig. 2 is used; in this case the bottom-wall sticks are anchored to the rock by iron bolts; but in some cases it becomes very expensive and consumes too much time to clear away the gravel, bowlders, &c., and construct tight coffer-dams, to admit of bolting the bottom timbers to the rock. In such cases a foundation-crib is placed, rising to the low-water level, and on this the superstructure is placed. The cross-section in this case would be as shown in Fig. 5. In all cases the crib is sheathed on the up-stream side, so as to be water-tight from bottom up to the crest, a backing of clay and gravel being placed against the sheathing.

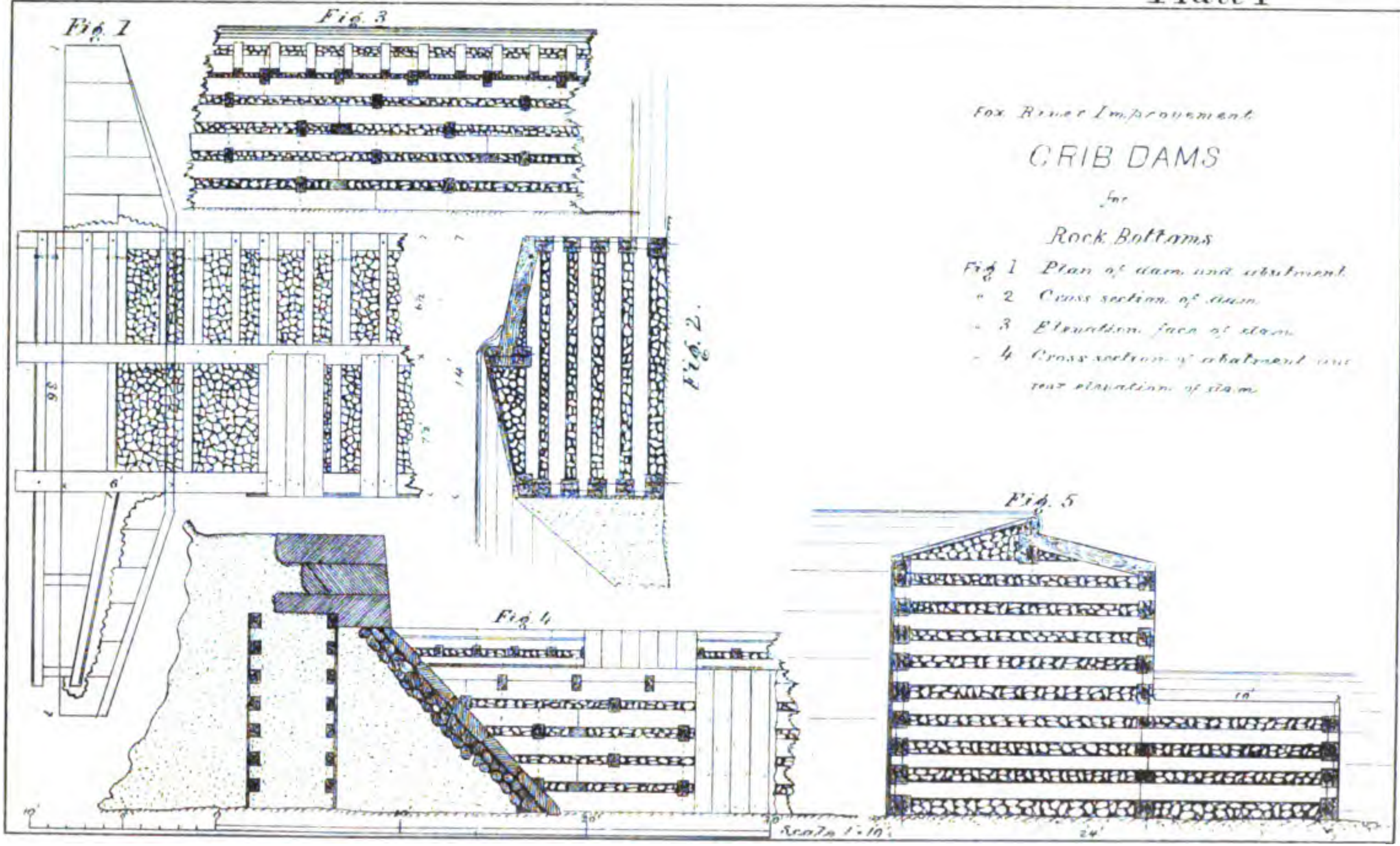
PLATE II.

Pile-dam for Little Kaukana. The bottom at this place is clay, or clay and gravel. The dam consists of two rows of piles, against the upper of which horizontal sheathing and sheet-piling are secured, to make it water-tight. The upper is braced against the lower row by inclined braces, which also form supports for the apron of oak planking. The piles of the upper row are driven 3 feet apart, center to center; those of the lower row, at double the distance. Between these two rows, and extending as far below the dam as may be necessary, stone is solidly filled, and against the sheathing, on the up-stream side, a substantial embankment of clay and gravel, faced with stone, is placed.

PLATE III. (*a*.)

This illustrates a method, which it is proposed to try, in hanging gates for the new locks. A wrought-iron bar (B) is rigidly attached to the frame-work of gate at top; its inner end is formed into an axle, for two horizontal wheels, (*d*, *d*,) which, when the gate is in motion, roll against the circular tracks, (*a*, *a*, *a*.) The faces (*b*, *b*) of this track are circular in plan, the center being at the center of motion of the gate. They are held in position by three wrought-iron straps, (S, S, S,) in pairs, so arranged as to allow the wheels to traverse between them; they are connected with the main anchoring-rods by means of sleeve-nuts at (L, L, L,) through which the position of the tracks is accurately adjusted to the center of motion. This method has not been put in practice as yet on any of the locks; nor is it believed that it has ever been in use, but trials, made under very unfavorable circumstances, promise most favorable results, and it is expected that one man will be able to move our heaviest gates with ease. The center of motion does not coincide with the center of hollow quoin, but is about half an inch from it, so that the quoin-post moves clear of the surface of the hollow quoin as soon as the gate begins to swing.

Plate I



Fox River Improvement

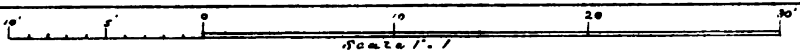
CRIB DAMS

for

Rock Bottoms

Fig 1 Plan of dam and abutment
" 2 Cross section of dam
" 3 Elevation face of dam
" 4 Cross section of abutment and rear elevation of dam

Plate II



Fox River Improvement

PILE DAM

for

Little Kaukauna

Fig 1 Plan
" 2 Section
" 3 Front Elevation

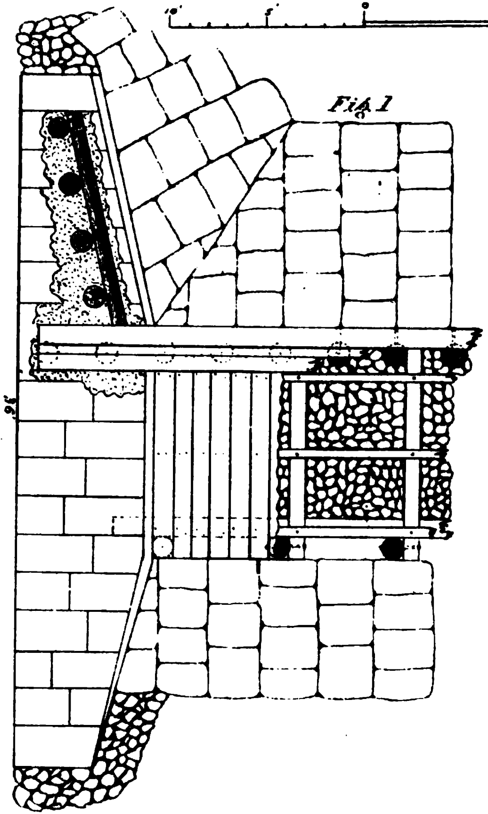


Fig 1

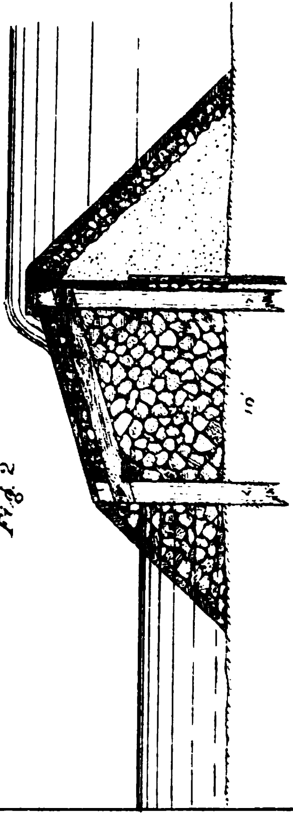


Fig 2

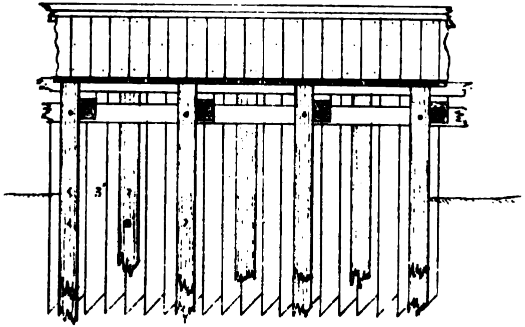
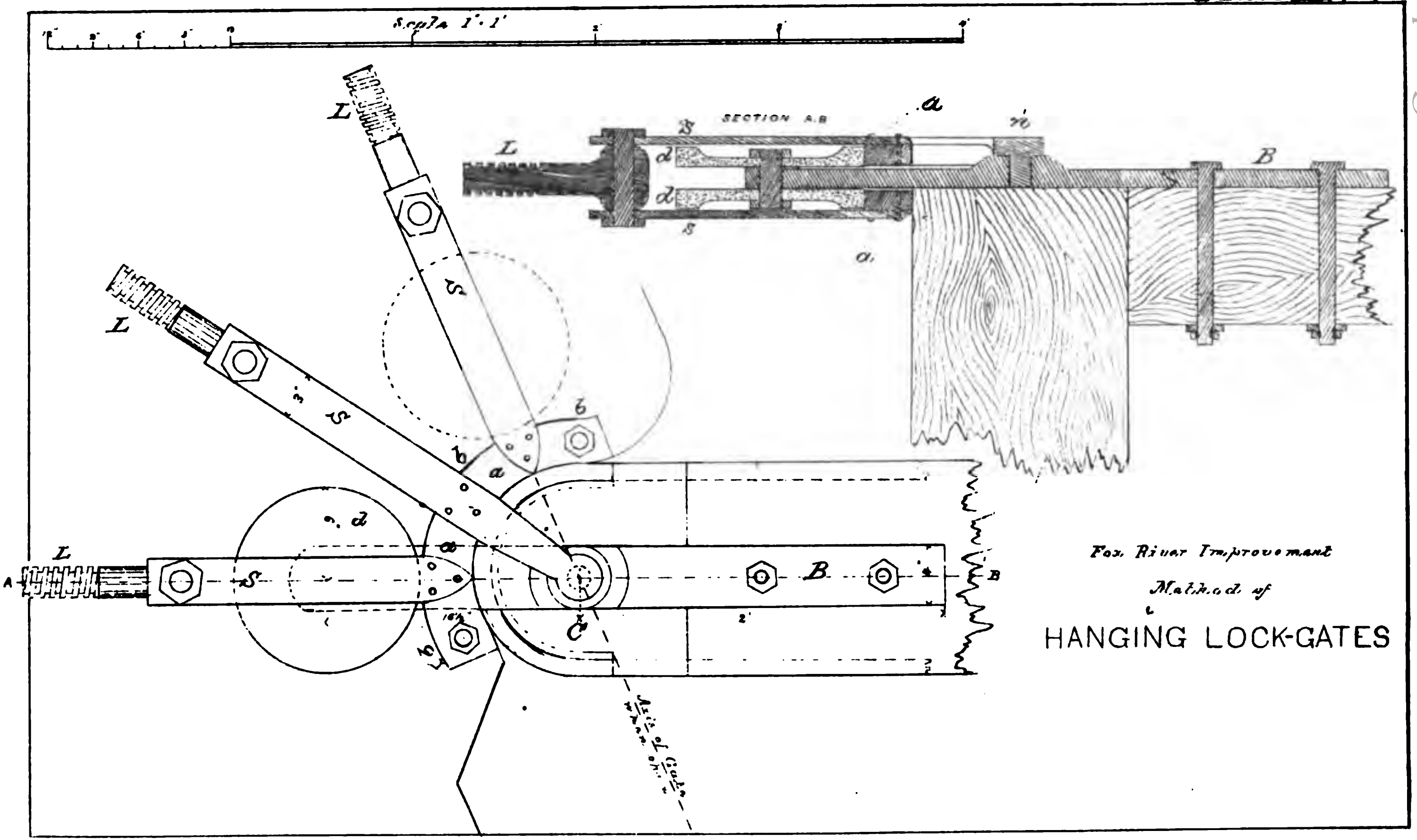


Fig 3

Plate III (a)



Fox River Improvement

Method of

HANGING LOCK-GATES

Plate III (h)

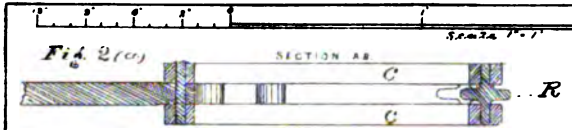


Fig. 2 (a)

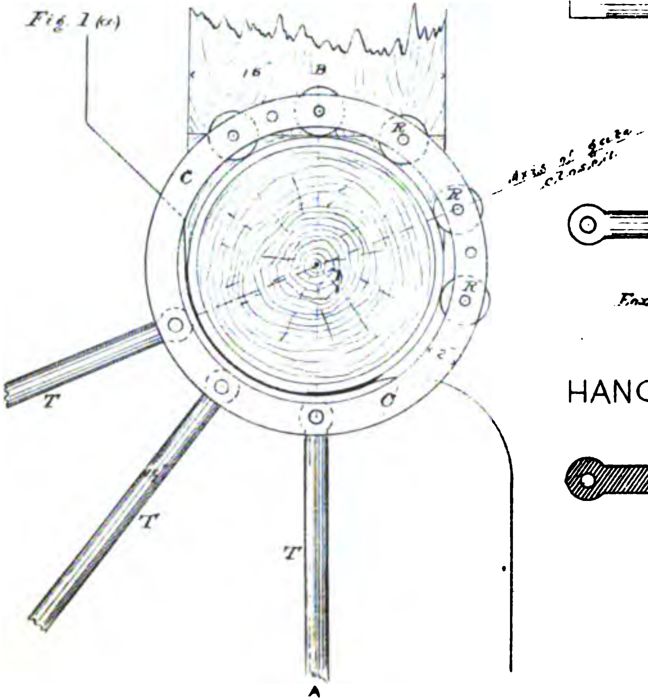


Fig. 1 (a)

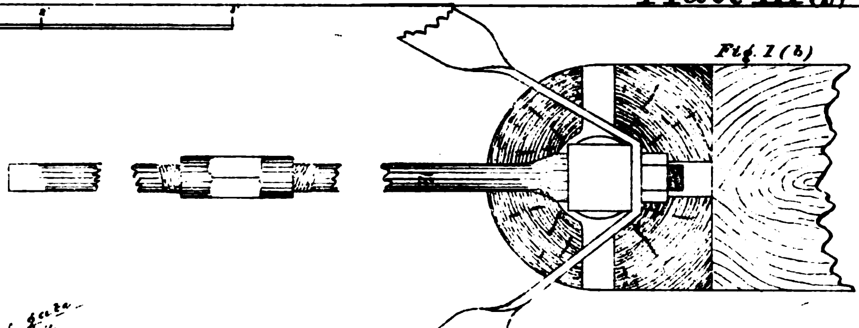
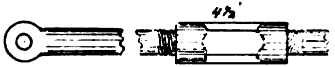


Fig. 1 (b)



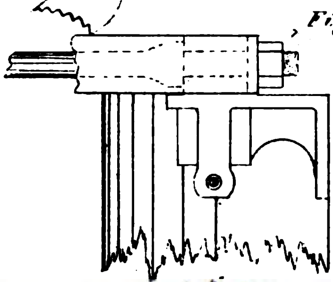


Fig. 2 (h)

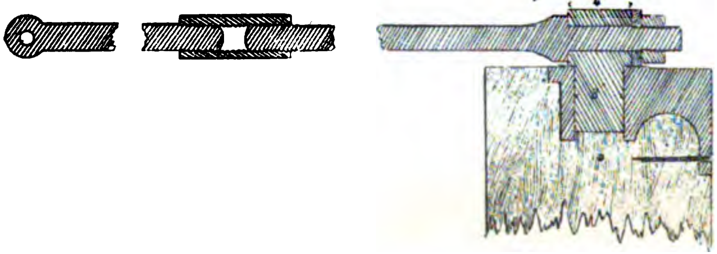


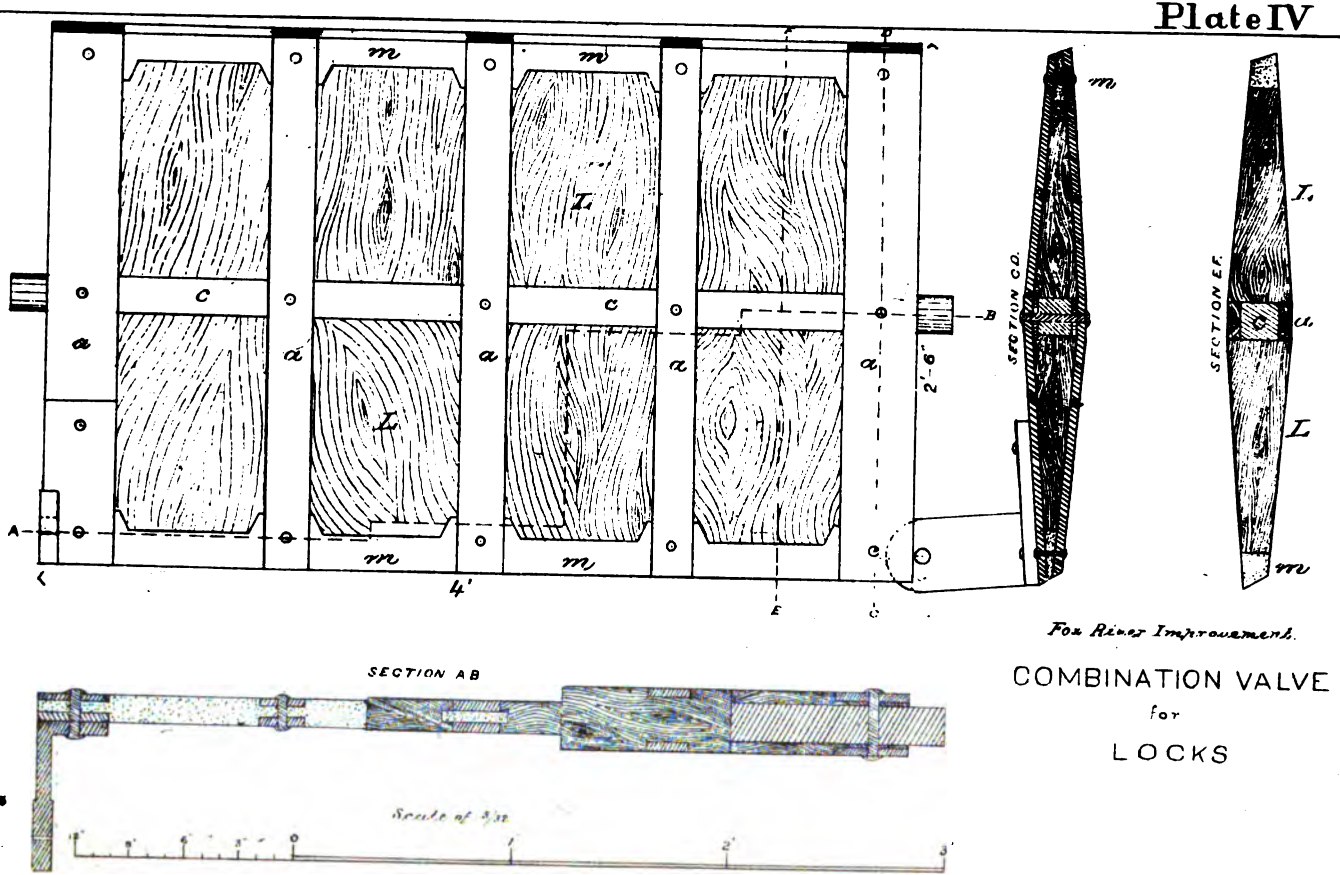
Fig. 3 (h)

Fox River Improvement

Methods of

HANGING LOCK-GATES

Plate IV



Fox River Improvement.

COMBINATION VALVE
for
LOCKS

Plate·V.

Fig. 1.

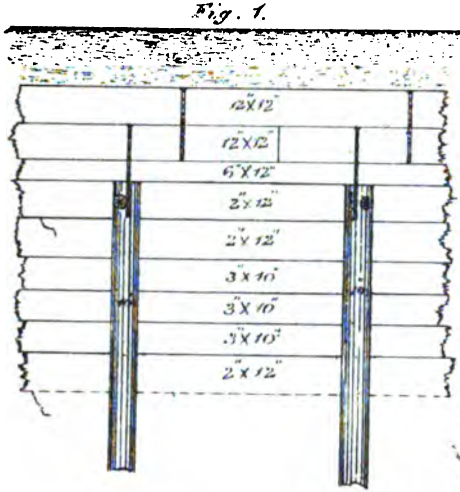


Fig. 2.

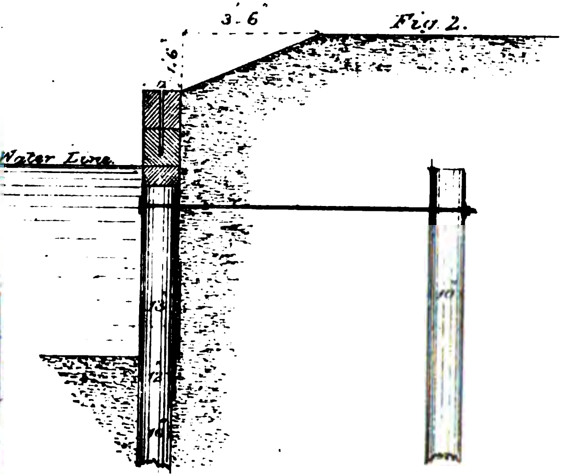


Fig. 4.

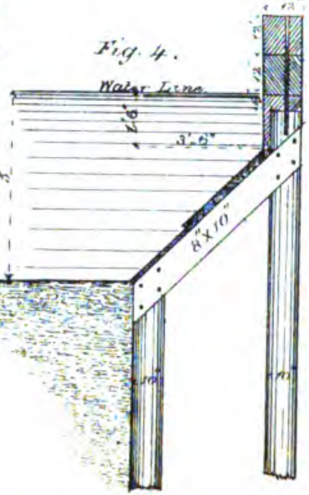
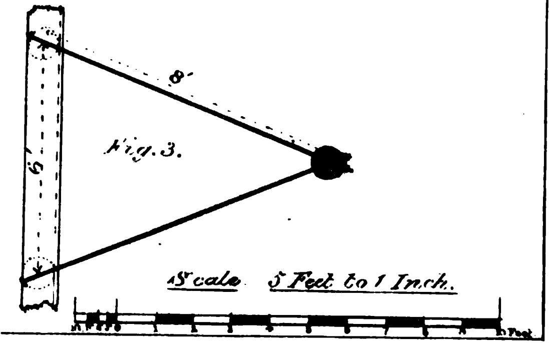


Fig. 3.



Scale 5 Feet to 1 Inch.

Fox River Improvement.

REVETMENT
for
PORTAGE CANAL.

PLATE III. (*b.*)

This plate shows the two methods of hanging lock-gates, under trial at the Winnebago Lock. In the first method, shown in Figs. 1, (*a*,) 2, (*a*,) and 3, (*a*,) 2 wrought-iron collars (*c*, *c*) contain between them 5 friction-rollers, (R, R, R,) the centers of which are so placed that when in position they will be at equal distances from the center of motion of the gate. The top of quoin-post is worked to a cylindrical surface, on which a wrought-iron band is secured. The collar with friction-rollers is secured in position by anchor-rods, (T, T, T,) in such manner that the quoin-post at top rests against the friction-rollers and moves on them when the gate swings.

In the second method, a cast-iron socket is framed into the top of the quoin-post to receive a pin secured into the lock's walls, and adjusted to the center of motion of the gate. As in the method shown on the preceding plate, the center of motion does not coincide with the center of hollow quoin. This method has not proved very satisfactory so far, the method first described above allowing the gates to be maneuvered much more easily.

PLATE IV.

This shows the construction of a valve of wrought iron and oak which will be tried in our new works as a substitute for those of cast iron, which have been in use heretofore; the advantages being they are lighter and less liable to break. The valve consists of a central shaft, (*c*, *c*,) with trunnions turned on each end; wrought-iron straps (*a*, *a*, *a*) encircle the two wedge-shaped pieces of oak, (L, L,) which form the body of the valve and in connection with the strips (*m*, *m*) on each edge bind all the parts together.

PLATE V.

The revetment for Portage Canal is illustrated in this plate. In Figs. 1, 2, and 3 are shown the plan, section, and elevation of the original system, while Fig. 4 indicates, in cross-section only, the modified system to which we changed when it was no longer practicable to make use of the tie-piles and land-ties of the first system. In the first system *one* tie-pile was used for every *two* main piles in the front row; and from this pile two iron tie-rods passed diagonally to the two nearest piles in the main row. A tight sheathing of jointed plank was spiked against the back of main piles; these piles were capped with a $\frac{6}{12}$-inch timber, the upper surface of which is at the low-water line, the balance of revetment consisting of 12 inches by 12 inches timbers.

In the modified plan (Fig. 4) a brace-pile was driven to the level of bottom of canal, in front of each pile of the main row, and against these inclined braces were framed at an angle of 45°. In this case the sheathing was placed on the *braces* and not in rear of the piles.

G. J. LYDECKER,
Captain of Engineers, U. S. A.

WISCONSIN RIVER.

V.—REPORTS OF LIEUTENANT F. A. HINMAN, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Madison, Wis., December 9, 1875.

SIR: Pursuant to your orders of October 12, 1875, I have the honor to submit the following report "bearing on the practicability of the present system of improvement" of the Wisconsin River.

The work of the season just closed consisted in removing snags and leaning timber, and also in perfecting and constructing a portion of the dams and shore-protections required to complete the sections of the river where work had been done in former seasons.

The detailed operations of the two working-parties are well set forth in the accompanying reports of Overseers J. R. Berthelet, jr., and Ed. C. Hinman.

A platted record of water-gauge readings since June 30, 1875, together with two sketches of portions of the river, are herewith submitted. The latter show the lengths and locations of all dams, &c., that have been built to date; the estimated lengths and sites of dams required to complete the partially-improved sections; the dams repaired during the season just closed, and also the soundings taken last October in the improved portions of the river. The rapid changes (for the better) and the results obtained in the channel of the completed sections this season are very encouraging. The soundings average over 5 feet, and show that there are plenty of deep pockets to accommodate the sand that, it is thought, must and will leave the shoaler places in time. The channel is well described in the reports referred to above.

As much stress is laid by some on the time (5 years) already spent on the improvement, the following observations may not be inappropriate. I find the following reported on page 243, Report of the Chief of Engineers, 1873: "The work of the improvement of the Wisconsin River was commenced on the 26th of June, 1871, and partook of an entirely experimental nature, the object of the experiments being to test the possibility of making the necessary canal-crossings in the river, in case the canal-plan should be adopted, and at the same time to test the possibility of improving the natural river-bed. After the necessary preparations, the work was commenced on the upper proposed canal-crossing, about 5 miles below Portage City, by closing the left-hand channel between Pine Island and the left bank. The dam is 700 feet long, and built in an average depth of 2 feet of water. Owing to the absence of materials in the immediate vicinity, the work could not be carried on as proposed, and owing to the continued low water of the season, and the impossibility of obtaining suitable boats, the work was a continuous strife throughout the season. A commencement was also made on the improvement of the middle canal-crossing near Lone Rock.

"Here the same difficulty occurred as at the upper crossing, (the absence of materials in the immediate vicinity of the proposed work,) and it became necessary to improve a portion of the river above the proposed work."

The records further show that during the first years of the improvement many experiments were made before the present method of building dams was decided upon; for example, dams were built of rope and brush, of boxes filled with sand, of brush and sand-bags, of brush and sand, of long fascines and of short fascines (gabions) filled with stone. Captain Bell's method of building dams was tested, and a "section dam" was also built.

I also find that the season of 1873 was "practically closed on October 15, 1873, for want of funds, and no appropriation being made so as to be available before the end of the fiscal year, the work necessarily remained in the same condition as at the end of the season of 1873," (page 167, Report of the Chief of Engineers, 1874,) so that the working season of 1874 opened late, (July 1.)

From the above it is evident that much time was consumed during the four seasons preceding the one just closed in experimenting, and also in perfecting the plan of improvement adopted, and acquiring facilities for carrying it out; also, that much time was lost through lack of funds; so that not until the present working season has the work progressed untrammeled.

The natural working season is limited by the spring rise and the freezing of the river in November. A little over two years' time has been spent on actual construction of dams.

There are those so inconsistent as to condemn the present wing-dam system of improvement, and yet they earnestly advocate General Warren's "third plan," which contemplates the improvement by "10,000 feet of wing-dams" of reaches of river (at the canal-crossings) from 2,300 feet to 2¼ miles in length, (in all over 4 miles.) If such lengths can be improved, why not the whole river?

The opinion heretofore expressed by me in favor of the present system of improving the river remains unchanged.

My thanks are due to Overseer J. R. Berthelet, jr., and Ed. C. Hinman, for the zeal, ability, and intelligence with which they have discharged the arduous and varied duties assigned them.

SUMMARY STATEMENT OF WORK DONE.

To June 30, 1875, built	119 dams	48,757 linear feet, including spurs.
Since June 30, 1875, built	31 dams	17,214 linear feet, including spurs.
To date, built	150 dams	65,971 linear feet, including spurs.
June 30, 1875, built	1 bank-protection,	2,475 linear feet.
Since June 30, 1875, built	4 bank-protections,	2,293 linear feet.
To date, built	5 bank-protections,	4,768 linear feet.
To June 30, 1875, pulled		47 snags.
Since June 30, 1875, pulled		1,168 snags.
To date, pulled		1,215 snags.
To June 30, 1875, felled		642 leaning trees.
Since June 30, 1875, felled		5,178 leaning trees.
To date, felled		5,820 leaning trees.

To date, improved 28 miles of river.
To date, partially improved 18 miles of river.
To date, constructed and repaired boats, implements, &c., as required.

The completed sections of the river will require some additional work in future. It is thought, with the organization proposed, that 40 miles of river (including the 18 partially improved) could be completed next season.

Very respectfully, your obedient servant,

F. A. HINMAN,
First Lieutenant of Engineers, U. S. A.

Maj. D. C. HOUSTON,
Corps of Engineers, U. S. A,

REPORT OF MR. ED. C. HINMAN, OVERSEER.

WISCONSIN RIVER IMPROVEMENT,
Portage, Wis., November 30, 1875.

SIR: In accordance with your instructions of September 20, I have the honor to submit the following report of operations of the upper party on the Wisconsin River improvement during the working season of 1875:

Owing to high water work was not commenced until May 24, it being impossible to cut brush in the bottom-lands previous to that time.

The party was temporarily divided into two subparties; one of these commencing at Portage, the other at Merrimac; the purpose of both being to make necessary repairs over the whole portion of the partially improved upper section.

The dams in most cases were found to be in good condition, many of them requiring only slight repairs; others having been built low originally, were raised, in accordance with your order of June 30, 1875. Only one of the dams on the lower portion of this section, built during the working season of 1874, needed repairing, and then only partially. I attribute this to the plan on which they were constructed, being the same as all new work of the present season.

During the time repairs were in progress, (about 6 weeks,) 34 dams, built during the year succeeding 1871, were repaired, and many of them for the first time. Hence, repairs were more extensive in many cases than they would have been had the system and facilities for working in former years been better.

July 15 repairs were completed over the Merrimac section; the two subparties were then consolidated, having an equipment consisting of United States steamer Portage, United States steam-scows Boscobel and Dekorra, 2 quarter-boats, 2 large and 5 small scows, with a monthly average of 100 men all told. With this force work was commenced at Duck Creek Flats, with orders to put in the additional proposed work necessary to secure the required channel over this partially improved section. The above-named flats were known to all persons who ran the Wisconsin on rafts, or who have been connected with the improvement, as a portion of the river blocked by impassable sand-bars. These flats were improved by two dams from a low-water channel of 20 inches to one of 4 feet. At the mouth of the Baraboo a similar result was obtained. Pine Island Slough, above Dekorra, was improved from a low-water channel of 2 feet to 3½ feet. The river opposite Dekorra, from a low-water channel of 2 feet scant to 4½ feet. Allen's Flat's from a low-water channel of 19 inches to 3 feet. The work on these flats was not completed until the latter part of October, so that the time which has elapsed for the improvement obtained is very short, and we may reasonably expect 4 feet next spring. It requires more time for the channel to shape itself in some places than in others—according as the sand-bars are old or newly formed.

* * * * * * *

With the first cold weather "anchor" or slush ice rises from the bottom of the river and fills the channel completely. This continues until the temperature of air and water is in a measure equalized; gradually this ice, carried down with the current, becomes quite solid, and might damage the work were it not for the fact that before the running ice becomes solid, that portion of the river from the point of every dam up stream (on a line with the channel) to the main shore freezes over, so that the anchor-ice in passing a dam cannot strike it, but instead continues to remain in the channel. Should the ice go out with low water in the spring, that portion only which formed over the channel will move, while that above and below the dams will remain, protect the dams, and melt where it forms the same as it does in all bayous. In high water the water itself protects the dams from ice. The nature of the banks in many cases renders it necessary that the channel of the river should be confined to the middle of it, (as at Dekorra,) and in this way prevents the banks from washing out.

* * * * * * *

The river at this point (Portage) closed above the bridge November 23, but from below the bridge as far as the work extends, there is yet a clear open channel all the way, which must be free from sand-bars, else the anchor-ice would gorge and close the river. The water is lower than ever before—gauge reading 1.7 feet below 0 November

23. The weather has been very cold for several days, the thermometer reading 4° below 0, and on November 28 read 16° below 0. In all preceding years the Wisconsin River has frozen over before the Fox River, but the latter was closed at Portage November 24. This of itself is conclusive evidence that the shoal bars on which the ice has gorged in former years have been removed.

Rafts from the Yellow River have made trips almost every day during the past season. The average time consumed in the run from Portage to Merrimac, a distance of 17 miles, seldom exceeds 8 hours in the lowest water, while in former years the river was in some places almost impassable, and rafts were obliged to tie up and wait for a rise of water.

The opinion among raftsmen and well-disposed people who have taken pains to examine the work lately, seems to be that the present plan of improvement will ultimately prove a complete success.

There is in fact but little dissatisfaction among the people compared with that of former years. * * * * * On November 6, work on the river was suspended on account of cold weather. Up to this date 19 new dams were built—all of them wing-dams except 2, the balance on this reach having been built in former seasons. The river was also cleared of snags and leaning timber in the vicinity of said work, which was confined to the distance between Portage and dam No. 8, 1872, 12 miles. In every case the river has shown a rapid improvement after the completion of a dam, and the improvement of the river this year over that of last can be readily seen from a comparison of the soundings taken. Those taken this season (the gauge reading 0.2 foot above 0, or low water of 1872 at Portage) are more uniform and average much better. The shoalest water found on the completed portion was 3 feet. (The party was constructing dam No. 14, 1875, when said soundings were taken.) This, however, is more water than can be found on the Upper Mississippi River in dead low water.

We cannot expect to obtain the greatest results from the work in so short a time; but with another season of rise and fall of the water, the work completed will undoubtedly prove the wing-dam system as carried out on the Wisconsin River all that is expected.

* * * * * * *

RECAPITULATION OF WORK ACCOMPLISHED.

33 dams (15,575 linear feet) repaired during season of 1875.
19 dams (11,220 linear feet) constructed during season of 1875.
13 dams (5,656 linear feet) repaired since June 30, 1875.
18 dams (10,774 linear feet) constructed since June 30, 1875.
4 bank-protections (2,293 linear feet) built since June 30, 1875.
93 snags pulled since June 30, 1875.
1,071 leaning trees felled since June 30, 1875.

Respectfully submitted.

ED. C. HINMAN,
Overseer Upper Party Wisconsin River Improvement.

Lieut. F. A. HINMAN,
Corps of Engineers, U. S. A.

REPORT OF MR. J. R. BERTHELET, JR., OVERSEER.

WISCONSIN RIVER IMPROVEMENT,
Boscobel, November 29, 1875.

SIR: In accordance with your instructions of September 20, I have the honor to respectfully submit the following report of operations of the lower working-party of the Wisconsin River improvement for the season of 1875.

During the working-season just closed the lower party consisted of the following boats and men: Steamers Winneconne and L. W. Crane, 4 large and 2 small scows, also a quarter-boat, with a party of 70 men, (about the average of the season.)

The steamer L. W. Crane and crew with 5 laborers kept ahead of the construction party, felling the leaning timber and pulling snags along the partially improved channel.

This party passed over the river from Richland City to Boscobel during the season, and felled, since June 30, 4,107 trees that hung over the bank where the channel passed, and pulled from said channel since the above date 1,075 snags. The said timber and snags were trimmed of brush, cut up into lengths of 15 to 20 feet, and hauled back upon the bank beyond danger of being taken off by high water. The work of this party was as thorough as possible; during high water many snags were unavoidably passed, and at the low-water stage there were quite a number that could not be reached until the construction-party had done its work.

The work of this snagging party greatly benefited navigation, and thus assisted the construction-party which followed. Raftmen will miss many a familiar leaning tree and snag that have annoyed them for years, and will find accessible landings along banks they have heretofore avoided.

* * * * * * *

During the working-season just closed the construction-party under my immediate charge passed over the river from Richland City to Boscobel, (a distance of 23 miles;) it built 7,020 feet of new work, and repaired 10,221 feet of old on this section.

On June 30 this party was at work upon "Muscoda Flats," having previously worked on that portion of the river between there and Richland City, since which date they have progressed toward Boscobel, and accomplished the following work: Built 13 dams, 6,440 feet, and repaired 20 dams, 6,850 feet.

It is my impression that more work was done this season on this section than during any previous season, probably owing to the better adaptation of the rebuilt steamer Winneconne and general outfit to the work, &c.

The repairs to old work made by this party were comparatively light, with the exception of those on 3 or 4 dams, proving beyond question the durability of dams, as the most of those repaired were constructed during the seasons of 1872 and 1873, having withstood the freshets and breaking-up of the ice for two and three seasons, and, as stated above, required but slight repair. Several of the old dams required no repairs, being in good condition and well sanded in; and it is my opinion that no further work will be necessary on any of the repairs made, with the exception of those on the three or four heavy settlements, which were like the building of new dams, and the brush may settle to some extent. It is thought that the dams of this season will require less repairs than those of former seasons, owing to their greater height, width, and strength.

I would respectfully invite your attention to the fact that repairing old work is slow and difficult; not so much the work of filling up the settlement, as the difficulty and labor of getting material to it. In nearly every case where repairs to old work were made, bars were found above the dam, or else the water was so shoal as to exclude the use of loaded scows, often necessitating the wheeling of material several hundred feet, Settlements of any consequence were found only where the dam was built in very shoal water, on a live or moving bar, or on a dry bar. The extension of old wing-dams offers obstacles that take much time and labor to overcome. At the end of old wing-dams the water is deep, and there is often a strong eddy, which makes it very difficult to sink mats, and, after overcoming this, there is also a cross-current to contend with the entire length of the extension.

* * * * * * *

After leaving Muscoda Flats (July 12) the party met with no difficulty until it reached the repairs and extension of dam No. 6, 1873, below which there was a flat bar extending from bank to bank, with but 18 inches of water over it. The material for this work being below the bar, the steamer Winneconne was forced over the latter, and wound the material for this dam over 1,500 feet. It was but a short time after completing said dam that the steamer Winneconne, drawing 24 inches, was enabled to run by it. Soundings now show a channel of 3¼ to 5 feet over this portion of the river.

The next point that gave the party trouble was that called "Pilling's Flats," or at dam No. 4, 1875, where a similar bar to that above was found, with but 14 inches of water over it. Again material was below the bar, and all used in the construction of dams Nos. 4 and 5, 1875, was wound by the steamer to the sites of said dams, she being anchored as low on the bar as possible.

Immediately after the completion of these two dams the said steamer ran over the said flats without difficulty. Soundings now show 5½ to 7 feet at this point.

A division of water at dam No. 9, 1873, caused by a heavy settlement in said dam between the islands, made a bar below which shut off the party from Port Andrew.

After the repairs were made to this dam we were enabled to reach the material secured below. Repairs from dam No. 9 to No. 13, 1873, were made during the rise of nearly 3 feet between the 5th and 24th of September.

Between dam No. 7, 1875, and the mouth of Blue River (Eaton's Flats) four new dams were built, each dam opening a channel for the moving of the working boats. Previous to the construction of these four dams there were four crossings on this flat with less than 18 inches of water on each. Soundings of recent date show but two of less than 3 feet, *i. e.*, 2 feet 10 inches. This portion of the river has always been a dread to river-men, but, in my judgment, it will hereafter be a good piece of river, as the flat is narrowed by these four dams to less than 600 feet, and, the Tiger Sloughs being effectually closed, the entire river flows through this contraction.

After completing the work over Eaton's Flat, it was thought advisable to pass over the section between the mouth of Blue River and Perdu Bay for the present, as that portion of the river is generally good, and the season being so far advanced as to leave barely time to do the proposed work in the vicinity of Perdu Bay and also have the boats convenient to winter quarters.

Accordingly, on the 28th of October, the boats and party were moved to Perdu Bay, and worked in that neighborhood until the 17th of November, when the boats were laid up for the winter.

* * * * * * *

The total results of the late work about Perdu Bay are not yet produced, as all the proposed dams for this vicinity are not yet built, though I am satisfied of a great improvement even now, as large quantities of sand have been put in motion.

Soundings taken over this section (Boscobel to Richland City) on the 29th of October show but three bars with less than 3 feet of water, and each one of these was a formation from the sand displaced by this season's work, not yet having found a resting-place in the slack-water formed by the dams. All of the *old* shoal crossings and bars have either disappeared or improved to an extent giving soundings of from 3 to 5 feet over them. I am confident of a well-defined channel of 4 feet (and a still further improvement with time) over this section at next season's low water, without further work, though it may be necessary to build the few dams marked on accompanying sketch to make the channel perfectly reliable. To show the reliability of the improved channel I would cite the following instance: October 30 the steamer Winneconne was run from Muscoda to Perdu Bay, in a heavy gale, without difficulty, while in the unimproved river it is impossible to run in windy weather, as the channel is not defined and the bars not visible, compelling boats and rafts to tie up. Immediately after freshets the river is very flat. This will be the case to a limited extent through the improvement, but the river will adapt itself to a good low-water channel much sooner in the *improved* portion than elsewhere.

* * * * * * *

In conclusion, I will say that all practical men along the line of the improvement are impressed with its ultimate success. Raftsmen and river-men generally are outspoken in praising the improvement, and I believe the community at large are well pleased with the work of the past season and the manner in which it has been executed.

Very respectfully, your obedient servant,

J. R. BERTHELET, JR.,
Overseer Lower Party, Wisconsin River Improvement.

Lieut. F. A. HINMAN,
Corps of Engineers, U. S. A.

VI.

UNITED STATES ENGINEER OFFICE,
Milwaukee, Wis., July 3, 1876.

SIR: I have the honor to submit the following report of operations on the Wisconsin River improvement, supplementary to that of December 9, 1875, for the fiscal year ending June 30, 1876.

Since the close of operations last fall the boats and other property have been guarded and put in good order; the repairs in most cases were very slight, some boats requiring none whatever. All boats, &c., were concentrated at Portage, Wis., this spring, after the ice went out of the river.

The stage of water has been excellent this year, the highest recorded at Portage being 6.3 feet, (May 3,) and the lowest 2.7½ feet above low water of 1872, so that at no time this season has it been possible to inspect the work at extreme low-water stage.

On the 1st instant, I inspected the upper section of the improved river. Frequent and careful soundings disclosed a 5-foot channel the entire length, excepting three soundings, 4.7 feet, 4.9 feet, and 4.4 feet, due to new work it is thought; the gauge reading at Portage was 4.7 feet above low water of 1872.

The shore protections were in good condition and the dams were in a remarkably fine state of preservation; a few will require repairs as was anticipated. As the river was high I had to judge mostly of the condition of the dams by the uniformity of the break or fall of water due to them; and, also, by the shape of the channel. Of course, the high-water channel is no criterion of what the low-water channel will be, for reasons given in previous reports, but it is thought that the soundings predict a better low-water channel this year than formerly. Dry bars were observed around many of the dams which were never before noticed at this stage of water. The channel in the completed portion is most probably located *permanently*, as it is in the same place as last year. Several river-men of experience have admitted to me that the improved river-channel was never so good and well defined as now. There being no boats on the lower section, I did not inspect it.

Work on the construction of dams and shore protections has not been resumed since the close of last season's operations, owing to lack of funds. It is designed to commence work on the extension of the upper section as soon as an appropriation becomes available.

Very respectfully, your obedient servant,

F. A. Hinman,
First Lieutenant, Corps of Engineers, U. S. A.

Maj. D. C. Houston,
Corps of Engineers, U. S. A.

VII.

United States Engineer Office,
Milwaukee, Wis., July 5, 1876.

Sir: In accordance with your order of February 21, 1876, I assumed charge of "the works on the Fox River above Lake Buffalo, including the Portage Canal," and now have the honor to submit the following report of operations on said works from the said date to the close of the fiscal year ending June 30, 1876.

1. GUARD-LOCK.

A coffer-dam was built just above this lock for the purpose of repairing the gates, on completion of which repairs the dam was removed, and the sand in the upper approach to said lock was removed by the aid of a scraper built for the Wisconsin River work. The scraper was rigged on a small scow maneuvered from a steamboat anchored a few hundred feet above the lock. The sand was scraped into and carried off by the current of the Wisconsin River. The excavations immediately above the lock-gates were made by means of a hand-dredge, and the sand in the lock-chamber was thrown out by shovels. This lock had not been used for some time previous to the 30th ultimo. It will now admit, in all stages of water of the Wisconsin River, of the passage of boats drawing 2.5 feet of water.

2. NEW GUARD-LOCK AND BASIN.

Land lying south of the Portage Canal, between the guard-lock and the Wisconsin street bridge, is now being condemned, on which it is designed to build at some time a new guard-lock adapted to a 5-foot channel, and a spacious basin for boats to turn in. The longer axis of the said lock will be nearly parallel with the current of the Wisconsin River, to afford easy access to boats entering it from said river. The river-bank between it and the old guard-lock will be strongly revetted with brush and raised. A brush-dam, to be built on the opposite shore, will throw the water across so as to keep the south entrance to the new lock free from sand, &c. Borings at the new lock-site have been commenced, but are delayed by high water.

3. PORTAGE CANAL.

Owing to the continued high water, the contractors, Messrs. Conro, Starke & Co. were unable to resume work on the canal until May 16, since which date the work was prosecuted diligently, and the contract-work completed the 30th ultimo. The remaining portion of the canal-bank (923 linear feet) which borders the land now being condemned will be protected by a temporary light brush-revetment, which will be finished in a few days.

The draw-bridge at Wisconsin street over this canal, maintained by the United States, was replanked, tightened, and timbers placed under both abutments down to the level of the canal-bed; the latter were securely braced against piles.

The temporary trestle-bridge constructed by the city of Portage over the canal at Ketchum's Point has been removed by said city. It is presumed that the city will wish to replace it with a draw-bridge.

A new timber waste-weir was constructed for this canal on the site of the old one, adequate as a feeder for the Fox River.

On the 30th ultimo water was let into the canal, and the United States steamer Boscobel ran from the Wisconsin River through the canal into the Fox River and back. The locks and bridges were all found to be in good order.

The surface-drainage from the streets of the city of Portage deposited 90 cubic yards of material in the canal during the past year. This was removed before the canal was opened.

Summary statement of work on canal.

	Excavation.	No. of piles driven.	Framing timber and plank.	Iron in work.
	Cu. yds.		*Feet, b. m.*	*Pounds.*
To February 21, 1876	119, 802. 00	5, 300	795, 492	81, 428. 00
Since February 21, 1876	12, 077. 23	572	115, 795	6, 637. 75
To June 30, 1876	131, 879. 23	5, 872	911, 287	88, 065. 75

The material excavated for the canal was dumped along the bank of the Wisconsin River from the guard-lock down, making the bank at this point higher and stronger. The longest haul was 2,000 feet.

4. WINNEBAGO LOCK.

The coffer-dam below this lock, and also the remains of the one above, were removed. The sand immediately above the upper gate was removed by a hand dredge; minor repairs were made to the gates and small sections of the walls were refilled with material.

5. GOVERNOR'S BEND LEVEL.

On the 15th of May, Messrs. Conro, Starke & Co. commenced dredging out the sand-bar (1,900 feet in length) that had formed just below Winnebago Lock, to secure a depth of 5 feet, the width of the river, which averages about 70 feet. From the said date to the 1st instant, 14,837 cubic yards of material have been excavated over a distance of 3,150 feet. The dredge became the property of the United States the 1st instant. A large scow will be constructed to replace the two small ones that now carry it. Its capacity on this work is about 40 yards an hour. It will work for the present on the shoalest places in order to secure a fair channel as soon as possible. The dredging, hereafter, on this level will be very light to secure a 5-foot channel.

A few weeks since the Wisconsin Central Railroad Company obtained the consent of the United States to construct a "jack-knife" draw-bridge across this level about 2 miles below Winnebago Lock. One of the conditions was that the water-way should be entirely unobstructed by the said bridge. A recent inspection disclosed the fact that the said condition was not being complied with, and the company was notified to remove the obstructions (piles) or an injunction would be applied for. The engineer of the company has notified me that he will remove the piles and change the approaches so that the bridge will cross the river squarely instead of obliquely as proposed.

6. GOVERNOR'S BEND DAM AND LOCK.

The dam was strengthened and minor repairs made to the lock. The sand was flushed out of the latter.

7. MONTELLO LEVEL.

It is proposed to dredge on this level as soon as the dredge finishes above.

Through navigation over the above sectio s will probably be opened the 7th instant

Very respectfully, your obedient servant,

F. A. HINMAN,
First Lieut. Corps of Engineers, U. S. A.

Major D. C. HOUSTON,
Corps of Engineers, U. S. A.

LETTER OF THE CHIEF OF ENGINEERS ON THE SUBJECT OF LOWERING THE DAMS AT THE OUTLETS OF LAKE WINNEBAGO.

OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., May 8, 1876.

SIR: I beg leave to invite attention to the accompanying copy of the report of Maj. D. C. Houston, Corps of Engineers, dated 1st instant,[*] on the subject of lowering the dams at the outlets of Lake Winnebago, known as the Neenah and Menasha Channels of Lower Fox River, and in connection therewith, to the act approved March 3, 1875, entitled "An act to aid in the improvement of the Fox and Wisconsin Rivers, in the State of Wisconsin." This act contains the following clause:

> In case any lands or other property is now, or shall be, flowed or injured by means of any part of the works of said improvement heretofore or hereafter constructed, for which compensation is now or shall become legally owing, and, in the opinion of the officer in charge, it is not prudent that the dam or dams be lowered, the amount of such compensation may be ascertained in like manner.

The officer of the Department of Justice appointed to "represent the interests of the United States in legal proceedings under this act, and for flowage-damages hereinbefore described," appears to have acted under the assumption that because the dams in question had not been lowered, it was the opinion of the officer in charge that they should not be lowered, and in consequence to have put the United States to considerable expense for surveys, investigations, &c., deemed necessary by him to protect the interest of the United States. As Major Houston justly remarks, "it would seem that the first thing to do would be to ascertain this opinion" of the officer in charge.

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[*] For Major Houston's report of May 1, 1876, see page ~~499~~. 29

It will be seen from Major Houston's report that awards have already been made to the amount of $70,000, and that a much larger sum will have ultimately to be paid if the liability of the United States is determined.

The dams which have occasioned the flowage referred to were, as stated by Major Houston, not constructed by the canal companies and are not at all necessary for the purposes of *navigation*, and so far as *that* is concerned, could not only be lowered but entirely dispensed with. The dams were built by a water-power company solely for their own use and profit, and for water-power purposes, thus raising the water-level and causing flowage for which they should be held liable.

It appears that when the State of Wisconsin "undertook the improvement of the Lower Fox for purposes of navigation, it made some arrangements with the owners of the dam at Menasha as a part of the route, retained the dam at the present height, and thus by some legal decision became liable for the flowage caused by the dams, which legacy it has bequeathed to its successors," the last of them the Government of the United States.

Major Houston is "of opinion that it is prudent that the dams be lowered so far as the Government is concerned, and as a practical solution of this matter which will relieve the Government," he proposes "to deepen the present canal to such depth that if the dams were removed there would be sufficient depth for navigation, or, what is better, cut a new canal to the same depth." Major Houston has had surveys made of various routes for a canal to secure the object in view, and considers the route marked C D on the accompanying sketch, in full red lines, as the best. The estimated cost of this he puts at $166,558, or, deducting the cost of the lock, which will have to be built in any event, and $25,000 which will be needed for various purposes, the cost will be reduced to $106,558.

I concur in the views expressed by Major Houston, and, with your approval, will, in the next annual estimates from this office, submit the above estimate for the proposed canal. In the mean time I beg leave to recommend that the honorable the Attorney-General of the United States be requested to give the necessary instructions to the United States attorney appointed to protect the interests of the United States in the claims for flowage under the act of March 3, 1875, "to aid in the improvement of the Fox and Wisconsin Rivers, in the State of Wisconsin," to resist all claims for flowage caused by reason of the construction of the dams at the Neenah and Menasha Channels at the outlets of Lake Winnebago.

Very respectfully, your obedient servant,

A. A. HUMPHREYS,
Brig. Gen. and Chief of Engineers.

Hon. ALPHONSO TAFT,
Secretary of War.

[Indorsement.]

The plans of Major Houston herein referred to are concurred in. The Attorney-General will be requested to defend the interests of the United States in suits for flowage-damages.

ALPHONSO TAFT,
Secretary of War.

MAY 17, 1876.

SPECIFICATIONS

—FOR THE—

CONSTRUCTION

—OF—

MATTRESS BOATS

—FOR THE—

MISSOURI RIVER IMPROVEMENT,

UNDER THE DIRECTION OF

MAJOR CHAS. R. SUTER,
CORPS OF ENGINEERS, U. S. A.,
NO. 1351 WASHINGTON AVENUE,
ST. LOUIS, MO.

March 17th, 1883.

COMMERCIAL
PRINTING Co.
ST. LOUIS

NO. 4.

SPECIFICATIONS

—FOR A—

MATTRESS BOAT.

This boat is to be 110" long (face to face of head-pieces) and 32" wide, with a 7" curved rake, rising 3" at each end. It is designed, when in use, to lie athwart the current, or at right angles to the bank line.

The low gunwale on the up stream side is to have a curved knuckle and a bilge kelson, the deck to curve fair to the incline under the ways. The high gunwale on the down stream side is to be straight and 4½" deep. The bottom is to be stiffened athwartships with heavy cross-bearers; the boat is to be stiffened laterally by a set of plank braces on top of floors in up stream compartment.

The boat is to be stiffened longitudinally, on the center line, by a Howe truss, of which the keel and kelson form the lower chord. The ways are to run, with a slope of 4 to 1 on the inclined deck, from the top chord to the forward gunwale. A back or working platform is to cover the down stream half of the boat, and is to be supported in such a manner as to provide room for a wire net device beneath, and a free and continuous space for the net to run out over the top chord.

The lumber is to be oak and white or southern yellow pine, as may be specified, all of which must be sound, without loose or rotten knots, square edged and full cornered, and the yellow pine especially free of sap.

The boat is to be built complete as set forth in these specifications, and as shown in the accompanying drawings. All material must be of good quality, and the work must be done in a thorough and workmanlike manner, and to the satisfaction of the Superintendent.

CROSS-BEARERS (*Oak*).

The boat, between rakes, is to be divided into twelve panels of 8$^{\text{ft}}$ each. At each of the thirteen panel points there is to be a cross-bearer, 9$^{\text{in}}$x21$^{\text{in}}$, made up of two pieces.

The lower piece is to be 9$^{\text{in}}$x9$^{\text{in}}$, jogged 2$^{\text{in}}$ over grub strake and boxed full thickness, 5$^{\text{in}}$ up and 5$^{\text{in}}$ on, into bottom strake of the high gunwale; it is to be notched 2$^{\text{in}}$ under binding strakes, main and bilge kelsons, and floor braces—all as shown. The upper piece is to be 9$^{\text{in}}$x12$^{\text{in}}$, boxed full thickness, 5$^{\text{in}}$ down and 4$^{\text{in}}$ on into the second strake of high gunwale, and 6$^{\text{in}}$ up and 3$^{\text{in}}$ on into the top strake of low gunwale; it is to be notched 6$^{\text{in}}$ over binding strakes and bilge kelson, and 3$^{\text{in}}$ over main kelson.

The high gunwale end of cross-bearer is to be drift-bolted to gunwale with two $\frac{5}{8}^{\text{in}}$ round bolts, 18$^{\text{in}}$ long, driven inclined from below through grub strake, and two bolts, 15$^{\text{in}}$ long, driven inclined from top, as shown.

The two pieces are to be bolted together with one $\frac{3}{4}^{in}$ screw bolt of 21^{in} clear length, head under cross-bearer and nut on angle strap at foot of main top timber. Round $\frac{3}{4}^{in}$ bolts, 24^{in} long, are to be driven from below through bottom and points riveted, two through the kelson and one through the binding strake on each side. Nine $\frac{3}{4}^{in}$ round drift bolts, shifted alternately on opposite edges, are to be driven at intermediate points as shown.

Limbers, $\frac{1}{2}^{in}$x3^{in}, are to be cut under the cross-bearers, near each end, in position to avoid seams in bottom.

HIGH GUNWALE.

The high gunwale is to be 4^{ft} 6^{in} deep over all and made up as follows:—

One *Grub Strake* of oak, 5^{in}x15^{in}, laid flat and bent up rakes, in three lengths as follows: 37^{ft} 10^{in}, 46^{ft} and 37^{ft} 10^{in}, scarfs to be plain, 6^{ft} long with 3^{in} nibs, and each bolted horizontally with four $\frac{5}{8}^{in}$ rivets; lower edge to be quarter round on a radius of 3^{in}.

One *Bottom Strake* of oak, 9^{in}x9^{in}, in lengths as follows: 11^{ft} 7^{in}, 46^{ft}, 46^{ft} and 19^{ft} 7^{in}; splices to be 6^{ft} hook scarfs with $1\frac{1}{2}^{in}$ nibs, nibs fastened.

One *Second Strake* of oak, 8^{in}x10^{in}, in lengths as follows: 28^{ft} 10^{in}, 46^{ft}, and 44^{ft} 10^{in}—scarfs same as in floor strake.

Two *Web Strakes* of oak or white pine, 6^{in}x12^{in}, in lengths as follows: 1st, 46^{ft}, 46^{ft} and 30^{ft}; 2d, 22^{ft}, 46^{ft}, 46^{ft} and 14^{ft}—scarfs, 6^{ft} hook with $2\frac{1}{2}^{in}$ nibs, nibs fastened.

One *Planksheer* of oak, 6^{in}x12^{in}, laid flat, in lengths as follows: 38^{ft}, 46^{ft} and 38^{ft}; hook scarfs, same as for web strakes, each bolted horizontally with four $\frac{5}{8}^{in}$ rivets.

Drift Bolts are to be of $\frac{3}{4}^{\text{in}}$ round iron, driven as follows: From below and 2^{ft} apart, in lengths of 33^{in}; and from top, 2^{ft} apart, in lengths of 36^{in}—all as shown.

All *Splices* are designed to be between panel points. The splices of the upper web strake, beneath the planksheer, are to be reinforced by an oak plank, 3^{in}x12^{in}—9^{ft}, well riveted and spiked to gunwale, drift bolted with $\frac{5}{8}^{\text{in}}$ round bolts from top of planksheer, and provided with table block, $1\frac{1}{2}^{\text{in}}$ thick, near each end. The splices of planksheer are to be reinforced beneath by an oak stick, 6^{in}x6^{in}—9^{ft}, well bolted to both planksheer and upper web strake with $\frac{5}{8}^{\text{in}}$ rivets, and provided with table block near each end, $1\frac{1}{2}^{\text{in}}$ thick and 12^{in} long, full width under planksheer.

A *Filling Piece* of oak, 3^{in} thick and 18^{in} deep, is to be fitted down against grub strake at each rake and well spiked to gunwale.

All gunwale *seams* are to be *outgauged* $\frac{1}{4}^{\text{in}}$ on a depth of 2^{in}.

A *Top Timber* of oak, 6^{in} x 8^{in}, flat to gunwale, is to extend from grub strake to planksheer, in the middle of each panel, and is to be bolted to each strake with two $\frac{1}{2}^{\text{in}}$ rivets.

A *Main Top Timber* of oak, to act as a fender stanchion and a back support of the platform as well, is to be placed at each cross-bearer or panel point. Each timber is to consist of a 6^{in}x6^{in} oak stick, filled in beneath planksheer and out flush with gunwale above with 6^{in} oak blocks; it is to incline 15^{in} inside and extend from cross-bearer to under side of platform planksheer, 30^{in} above gunwale. The 6^{in}x6^{in} stick is to be tenoned to fit mortise, 3^{in}x6^{in}—4^{in}, in cross-bearer and pinned, and tenoned at the top, 2^{in}x6^{in}, into mortise of platform planksheer.

The *Main Top Timber* is *to be secured* as follows: It is to be bolted at foot with one $\frac{3}{4}^{in}$ screw bolt through gunwale, head flush outside, nut on angle strap inside—said strap to be $\frac{1}{2}^{in}$x3^{in}. with 1^{in} nib, and to be bolted to cross-bearer as before described; it is to be bolted with two $\frac{3}{4}^{in}$ screw bolts at middle, one through planksheer and one through gunwale 3^{in} below planksheer, nuts inside and heads counter-sunk in outside strap; it is to be bolted near top with one $\frac{3}{4}^{in}$ screw bolt, head counter-sunk in strap outside and nut on strap draw bolt inside. The strap draw bolt is to be $\frac{3}{8}^{in}$x$2\frac{1}{2}^{in}$ with $\frac{3}{4}^{in}$ nib and drawn to $\frac{3}{4}^{in}$ bolt, nut to screw down on outside strap on top of platform planksheer. A $\frac{5}{8}^{in}$ draw bolt, 10^{in} long, is to be placed through strap near outer edge. The timber is also to be riveted with two rivets below planksheer and two above. The *outside strap* is to be $\frac{3}{8}^{in}$x$2\frac{1}{2}^{in}$, 44^{in} long on face with $\frac{3}{4}$ nib and let in flush, and 10^{in} long on top of platform planksheer, and provided with holes for the bolts and rivets already described.

KEEL AND KELSON (*Oak*).

The *keel* and *kelson* together constitute the lower chord of the truss.

The *keel* is to be 6^{in}x12^{in}, notched up 3^{in} on to floors and cross-bearers; it is to be in lengths of 25^{ft} 3^{in}, 46^{ft} and 41^{ft} 3^{in}, with plain scarfs, 6^{ft} long and 3^{in} nibs, each bolted horizontally with three $\frac{5}{8}^{in}$ rivets, and nibs fastened.

The *kelson* is to be 10^{in}x12^{in}, notched 4^{in} over floors and lower piece of cross-bearer and notched 1^{in} under upper piece of cross-bearer, leaving a net section of 5^{in}x12^{in}; it is to be in lengths of 42^{ft} 5^{in}, 46^{ft} and 26^{ft} 5^{in}, with plain scarfs, 6^{ft} long and 3^{in} nibs, each bolted horizontally with three $\frac{5}{8}^{in}$ rivets, and nibs fastened.

The kelson and keel are to be bolted together with $\frac{5}{8}^{\text{in}}$ round bolts, driven from below and riveted, one on each side of each floor and cross-bearer alternately on opposite edges; two 8^{in}x $\frac{3}{8}^{\text{in}}$ spikes are to be driven through the keel into each floor.

The kelson is to be completed up rake by an oak piece, 12^{in}x 14^{in}, the two upper floor spaces filled in with chocks, and the keel carried up with a 3^{in} plank, all well spiked and riveted in the same manner as amidships, substantially as shown.

Binding Strakes (*Oak*).

There are to be three binding strakes on top of floors, each 7^{in}x 8^{in}—108^{ft} 10^{in}, one 8^{ft} from center line on high side, one 6^{ft} 7^{in} and one 12^{ft} 11^{in} from center line on low side, all slit and bent up rakes as shown; they are to be notched 1^{in} on top through cross-bearers and fastened thereto as elsewhere described, and fastened to each floor with one $\frac{5}{8}^{\text{in}}$ round bolt, driven from below through bottom and riveted; the timber is to be of good length and all splices well shifted.

Floor Timbers (*Oak*).

The floors are to be 3^{in}x 7^{in}, spaced 18^{in} centers between panel points or at uniform intervals of 15^{in} in the clear; the floors up each rake are to be at equal intervals of about 11^{in} in the clear, measured on lower edges; they are to be jogged down 2^{in} on grub strake and boxed into floor strake full thickness, 5^{in} on and 5^{in} up, and fastened with a $\frac{5}{8}^{\text{in}}$ round drift bolt, 18^{in} long, driven inclined from below through grub strake as shown, and a 9^{in}x $\frac{3}{8}^{\text{in}}$ spike at edge of grub strake.

The grub strake is to be spiked to floor strake with one 10^{in}x $\frac{3}{8}^{\text{in}}$ spike opposite the ends of floors, and at least one in each space between floors.

The floors are to be fastened to binding strakes and to the keel and kelson as already specified.

Limbers, $\frac{1}{2}^{\text{in}}$x 3^{in}, are to be cut under each floor, near grub strake and futtock, in position to avoid bottom seams.

Low Side or Gunwale.

The low side or gunwale is to consist of a curved knuckle, 18^{in} radius, a gunwale timber, a curved deck and a fore and aft piece carried on cross-bearer blocks.

The *Futtocks* are to be of oak, 3^{in} thick, at an angle of 45 deg., bolted to the floor ends with two bolts to each futtock and spiked to *filler futtocks*; there is to be a futtock on each side of cross-bearer, spiked thereto. The futtocks are to butt against the top gunwale timber.

Drift Bolts, $\frac{5}{8}^{\text{in}}$ round—27^{in} long, are to be driven inclined from top of gunwale timber, as shown, one down through each filler futtock and floor end, and two through each cross-bearer end.

The *Bilge Kelson* is to be of oak, 3^{in}x 18^{in}, beveled to gunwale, and jogged over floors and spiked thereto; it is to be notched top and bottom through cross-bearers, as shown. It is to be in good lengths with scarfs over four floors.

The *Knuckle* is to be made up of five strakes, of 4^{in}x 6^{in} oak plank, in lengths of not less than 40^{ft}, except to complete a strake; all butts are to be made on ends of cross-bearers, only one butt to each cross-bearer. The top strake is to be drift-bolted with $\frac{1}{2}^{\text{in}}$ round bolts, 10^{in} long, to the gunwale timber in each floor space. Each strake is to be bolted through futtock and kelson at each futtock with one $\frac{1}{2}^{\text{in}}$ rivet on edge of strake, and spiked with one 8^{in}x $\frac{3}{8}^{\text{in}}$ spike on opposite edge, bolts and spikes to alternate on opposite edges. The knuckle is to be moulded at the rake out to a horizontal line on the head-piece.

The *Gunwale Timber* is to be of oak, 8^{in} thick, 10^{in} deep outside and beveled to deck; it is to curve over rake to the top of the head-piece at its face; the curved pieces are to be $14^{\text{ft}}\ 3^{\text{in}}$ long, and the balance of the timber is to be in not over three lengths; the splices are to be 6^{ft} hook scarfs each bolted with not less than four $\frac{5}{8}^{\text{in}}$ bolts. The gunwale timber is to be secured to the end of each cross-bearer with one $\frac{3}{4}^{\text{in}}$ draw bolt, 2^{ft} long, head flush outside.

The *Fore and Aft Piece* is to be of oak, 10^{in} thick, 12^{in} deep at inside edge and beveled to deck, placed $14\frac{1}{2}^{\text{in}}$ clear above cross-bearer, or $38\frac{1}{2}^{\text{in}}$ above bottom, and inner face $3^{\text{ft}}\ 6^{\text{in}}$ from face of gunwale. It is to be supported on oak cross-bearer blocks, 6^{in} thick, 34^{in} long and 21^{in} greatest width, in form as shown; it is to be $107^{\text{ft}}\ 6^{\text{in}}$ long; in three lengths of $36^{\text{ft}}\ 9^{\text{in}}$, 46^{ft} and $36^{\text{ft}}\ 9^{\text{in}}$; the splices are to be 6^{ft} hook scarfs, reinforced by an oak cover, $4^{\text{in}} \text{x}\ 10^{\text{in}}$—$9^{\text{ft}}$, with one $1\frac{1}{2}^{\text{in}}$ table block at each end, and bolted with not less than six $\frac{5}{8}^{\text{in}}$ rivets through timber and cover.

An inch *screw bolt* is to pass down through fore and aft piece cross-bearer block, cross-bearer and binding strake at each panel point, nut flushed on top and head under cross-bearer. A $\frac{3}{4}^{\text{in}}$ round *drift bolt*, 3^{ft} long, is to be driven inclined through front end of block into cross-bearer as shown. Alongside of each block, a $\frac{3}{4}^{\text{in}}$ screw bolt is to tie the gunwale to the fore and aft piece, head flush outside.

The *Curved Deck* is to be of oak, seasoned or split heart plank, in six strakes, $3^{\text{in}} \text{x}\ 6^{\text{in}}$, dressed to a thickness;

the lengths are to be not less than 32^{ft}, except to complete a strake, and all butts are to be on cross-bearer blocks, not over two butts to any one block; the ends over rakes are to be moulded to a horizontal line at head-pieces. It is to be supported between blocks by short 3^{in}x6^{in} oak beams, three to each panel and four over each rake, curved to shape, and secured at each end by one 10^{in} spike. Each plank is to be spiked at each point of support with two 6^{in}x$\frac{5}{16}^{in}$ spikes and three spikes in each butt, the two lower strakes to be well spiked to gunwale.

One *Stanchion*, of 4^{in}x4^{in} oak is to be placed in the middle of each panel and well secured to binding strake and fore and aft piece.

All *Seams* are to be *outgauged* $\frac{1}{4}^{in}$ on a depth of 2^{in}.

FLOOR BRACES (*Oak*).

The floor braces are to be 2^{in}x10^{in}, placed on top of floor in up-stream compartment, in position as shown; they are to butt against main and bilge kelsons, halve together through cross-bearers, and notch $\frac{3}{4}^{in}$ under binding strakes; they are to be well spiked to each floor and cross-bearer.

BOTTOM (*Oak*).

The bottom planks are to be 3^{in} thick and in lengths of not less than 32^{ft}, except to complete a strake; all butts are to be on cross-bearers, well shifted, each butt bolted with one bolt; the rake plank are to be slit to light water to widths of not over 6^{in}, and all seams are to be *outgauged* $\frac{1}{4}^{in}$.

The bottom is to be fastened with 6^{in}x$\frac{5}{16}^{in}$ cut boat spikes, driven two to each floor and three to each butt in plank less than 14^{in} wide, and three to each floor and four to each butt in widths greater than 14$^{\text{in}}$. Planks are to be double-spiked to cross-bearers and back stick of head-piece.

HEAD-PIECE (*Oak*).

The head-piece is to have 12$^{\text{in}}$ face, top 4$^{\text{ft}}$ above bottom of boat, and is to be made of two pieces, each 10$^{\text{in}}$ thick.

The back piece is to have two tenons, full width of stick, 3$^{\text{in}}$ wide and 2$^{\text{in}}$ long, to fit mortises in high gunwale, and is to be secured thereto by two $\frac{3}{4}^{\text{in}}$ draw bolts, 2$^{\text{ft}}$ long, heads flush outside ; two $\frac{3}{4}^{\text{in}}$ round bolts are to be driven from below through grub strake, end of head-piece and planksheer, and riveted on top. The other end is to be secured to gunwale timber by one similar tenon and two draw bolts.

The bottom, knuckle and curved deck planks are to run across the back piece and double spike thereto.

The fore and aft piece is to be tabled and blocked to the binding strake beneath and bolted with two $\frac{3}{4}^{\text{in}}$ bolts, driven from below through bottom and floors, and riveted on top ; a $\frac{3}{4}^{\text{in}}$ screw bolt is to be put through the head-piece and timber ends—all as shown.

The other two binding strakes are to be boxed into square ends and each secured with one $\frac{3}{4}^{\text{in}}$ screw bolt through head-piece and bottom.

The kelson block is to be bolted with two $\frac{3}{4}^{\text{in}}$ screw bolts down through head-piece and bottom, and one $\frac{3}{4}^{\text{in}}$ draw bolt, 2$^{\text{ft}}$ long, from face of back head-piece.

The front stick of head-piece is to have two 3$^{\text{in}}$ tenons through high gunwale, and is to be drift bolted on each side of corner with two $\frac{3}{4}^{\text{in}}$ round bolts, 24$^{\text{in}}$ long, and bolted from below with two $\frac{3}{4}^{\text{in}}$ bolts riveted on top of planksheer; the other end is to have one similar inclined tenon through gunwale timber, and one drift bolt from face and two through gunwale timber. The lower edge is to be rabbeted to receive knuckle and bottom planks and grub strake, full thickness, and on to a line 5^{in} from face, measured along lower edge of bevel; the top is to be rabbeted 4^{in} on to receive curved deck.

The *Corner Straps* are to be $4^{\text{in}} \text{x} \frac{5}{8}^{\text{in}}$, two on each corner; they are to be turned down to 1^{in} nibs at ends, and are to be 30^{in} long on head-piece and 40^{in} long on sides; each strap is to have one $\frac{3}{4}^{\text{in}}$ screw bolt at end through head-piece, and three $\frac{3}{4}^{\text{in}}$ drift bolts, 18^{in} long, into head-piece; and, on side, two similar drift bolts into head-piece and two screw bolts through gunwale; the straps are to be let in flush, all heads countersunk. The straps on curved gunwale are to be bent to proper shape.

HOWE TRUSS (*Seasoned Oak*).

The truss is to be placed longitudinally on the center line. The lower chord has been described under the head of KEEL AND KELSON. The upper chord is to be 5^{ft} 6^{in} in the clear above the kelson and 8^{ft} over all above bottom, and the panel points of the truss are to be 8^{ft} apart.

The *Upper Chord* is to be 98^{ft} long, top curved as shown, with a greatest depth of 14^{in} and made up of five strakes, each $2\frac{1}{2}^{\text{in}}$ thick. The timber is to be in 40^{ft} lengths, except to complete a strake, with all butts midway between panel points as shown, each butt to be tabled for $\frac{3}{4}^{\text{in}}$ table block; the strakes are to be bolted together with ten $\frac{1}{2}^{\text{in}}$ rivets to each panel, as shown.

The *Brace Blocks* are to be 9^{in} face, and are to be 16^{in} long at top and 6^{in} deep, approximately; they are to be let into the under side of the chord $\frac{1}{2}^{\text{in}}$, the grain to run with the chord. The brace blocks at bottom are to be triangular and 12^{in} long, placed in the angles between kelson and cross-bearers.

The *Braces* are to be, one, 5^{in}x6^{in}, inclined toward the center, and two, 3^{in}x6^{in}, inclined toward the ends, to each panel ; they are to be notched together $\frac{1}{2}^{in}$ at intersection and bolted with one $\frac{5}{8}^{in}$—9^{in} screw bolt; the ends are to butt square on the brace blocks.

The *Truss Rods* are to be $1\frac{1}{4}^{in}$ diameter, two at each panel point, extending from under side of cross-bearer, outside kelson and 16^{in} apart, to top of chord and 5^{in} apart. The bolt at bottom is to be forged square beneath head and is to be provided with a washer of not less than 16 square inches area ; the bolt at top is to be the same, the two heads to be on strap washer, 4^{in}x$\frac{1}{2}^{in}$—9^{in}, all flush with top of chord ; the rods are to be screwed home with double cut sleeve nuts at the middle.

The *End Posts* are to be 8^{in}x8^{in}, placed as shown, with the same truss rods as amidships.

The *Rake Brace* is to be 6^{in}x8^{in}, placed as shown. The *Rake Tie* is to be $1\frac{1}{4}^{in}$, on top of brace, head on washer flush in top of chord, and nut on washer flush on underside of head-piece.

DECK (*Dry Pine*).

A *Deck*, 98^{ft} long, is to extend beneath the ways from chord to fore and aft piece ; it is to be laid fore and aft with $1\frac{1}{2}^{in}$ by not over 6^{in} dry white or yellow pine, dressed to a thickness and seams outgauged $\frac{1}{8}^{in}$; the decking is to be in lengths of not less than 20^{ft}, except to complete a strake, and butts are to be well shifted; it is to be spiked with 12d cut nails, two in each strake to each beam and three in each butt.

The *Beams* supporting deck are to be of oak, 2^{ft} centers, 3^{in}x4^{in} beneath ways and 2^{in}x4^{in}, intermediate; the lower ends are to be boxed into fore and aft piece, full size and 2^{in} on, and each secured with one 10^{in}x$\frac{3}{8}^{in}$ spike driven inclined, as shown. The fore and aft piece is to be rabbeted 2^{in} on, and edge of deck well spiked thereon. The beams at upper end are to be jogged 1^{in} and let in, flush at top, into a $2\frac{1}{2}^{in}$x8^{in} oak piece, well spiked to the face of the chord and brace blocks; the end of each beam is to be secured with one 6^{in} spike. The top of the $2\frac{1}{2}^{in}$x8^{in} plank is to be beveled and edge of deck well spiked thereto.

One *Stanchion* of oak, 3^{in}x4^{in}, is to be placed under each 3^{in}x4^{in} beam, heeled on cross-bearer or binding strake and well secured.

The chord and planksheer are to be tied together with a 1^{in} rod at each panel point, on the side toward the middle of the boat from the end; the nut to be on the lower end and the head to be flush with filling piece on back of chord.

WAYS (*Seasoned Oak*).

The ways are to be 3^{in}x8^{in} on edge, 4^{ft} centers, one at each panel point and one intermediate; they are to be flush with top of chord at upper end, and are to be curved over curved deck and carried to front edge of boat as shown.

Each way is to be *Bolted* to chord at top with one $\frac{1}{2}^{in}$—12^{in} drift bolt, to deck beam with four $\frac{1}{2}^{in}$ screw bolts, to fore and aft piece with one and to curved deck beams with two bolts, heads flush on top, all as shown.

The top of each way is to be quarter rounded and *covered* with a continuous strip of *band iron*, $\frac{1}{8}^{in}$x$3\frac{1}{2}^{in}$, shaped to way and secured by 1½$^{\text{in}}$ screws, No. 8, countersunk, 3$^{\text{in}}$ apart, but alternately on opposite edges; the ends are to be left flat, 4$^{\text{in}}$ on the chord and fastened with five 2½$^{\text{in}}$ screws, and 7$^{\text{in}}$ on face of gunwale and similarly fastened.

The chord is to be backed by a fillingpiece and the whole dressed to the shape shown and *covered with sheet iron*, ⅛$^{\text{in}}$ thick and 24$^{\text{in}}$ wide, in lengths so as to bring joints between ways and one foot therefrom, one joint in each panel of 8$^{\text{ft}}$. The sheets are to be fastened with 1½$^{\text{in}}$ screws, No. 8, countersunk, 6$^{\text{in}}$ apart at edges and 3$^{\text{in}}$ apart at ends; each joint is to be bedded on a strip of muslin, white leaded.

Everything under this head is to be specially well done.

PLATFORM.

The platform is to be 98$^{\text{ft}}$ long and 15$^{\text{ft}}$ 2$^{\text{in}}$ wide over all; it is to be 7$^{\text{ft}}$ 9½$^{\text{in}}$ above bottom at back edge, rising 6$^{\text{in}}$ to front edge; it is to be supported by the main top timbers, and by a line of supports, 6$^{\text{ft}}$ 3$^{\text{in}}$ from front edge.

The *Under Planksheer* on top of main top timbers is to be of oak, 3$^{\text{in}}$x12$^{\text{in}}$, secured as already specified; it is to be in three lengths with plain scarfs between panel points, each scarf bolted horizontally with three ½$^{\text{in}}$ rivets, and reinforced beneath by a plank, 2$^{\text{in}}$x12$^{\text{in}}$—7$^{\text{ft}}$ 6$^{\text{in}}$, well riveted. The back *guard rim* is to be of oak, 4$^{\text{in}}$x5$^{\text{in}}$, scarfed and well riveted to under planksheer.

The platform *Beams* are to be of pine, 2½$^{\text{in}}$x6$^{\text{in}}$—14$^{\text{ft}}$ 8$^{\text{in}}$, 2$^{\text{ft}}$ centers, placed as shown; they are to diminish, on a length of 5½$^{\text{ft}}$, to a depth of 4$^{\text{in}}$ at the inner ends; they are to be jogged down 1$^{\text{in}}$ over planksheer and each bolted thereto with two ⅜$^{\text{in}}$ rivets, and each is to be bolted to the stanchion stringer, $6^{ft}\,3^{in}$ from inner edge, with one $\frac{5}{8}^{in}$ rivet. The *under planksheer* at inner edge is to be 1^{in}x6^{in} oak, jogged up flush with bottom of beams and nailed thereto. The *guard rim* is to be 2^{in}x4^{in} nailed to ends of beams and to under planksheer.

The *Stanchion Stringer* is to be of pine, 4^{in}x7^{in}, center $6^{ft}\,3^{in}$ from inner edge; it is to be scarfed over stanchions and each scarf bolted with not less than three rivets and reinforced with 2^{in} plank. A *stringer guard*, 2^{in}x6^{in}, scarfed over three beams, is to be spiked to the underside of the beams.

The *Forward Supports* or braces of platform are to be oak, 4^{in}x5^{in}, in pairs at the panel points; they are to jog 2^{in} on top of and scarf to side of cross-bearers, and heel on top of binding strake as shown, each pair to be riveted through with one $\frac{1}{2}^{in}$ rivet; the tops of the pair are to diverge as shown, each to jog 3^{in} under string-piece and bolt thereto with one bolt.

The platform is to be laid with $1\frac{1}{2}^{in}$ dry pine, the same as the ways deck.

A *Stanchion* of oak, 4^{in}x4^{in}—30^{in}, is to be placed in the middle of each panel, from top of gunwale planksheer to under planksheer of platform and in middle of same, and well secured.

RAKE DECKS.

The rakes are to be decked over 7^{ft} back from face of head-piece, except a length of $7^{ft}\,2^{in}$ next to truss.

The *decking* is to be dry pine, 2^{in} by not over 6^{in}, laid parallel to head-piece, seams outgauged $\frac{1}{8}^{in}$ strong, and spiked down with 20d cut nails. It is to be supported by 3^{in}x6^{in} oak beams, 18^{in} centers, boxed in head-piece and in 4^{in}x10^{in} oak beam bearer as shown, and each end bolted with one 9^{in} bolt. The beam bearer of short deck is to be jogged 1^{in} and spiked to main top timber, and supported at other end by a 6^{in}x10^{in} oak stanchion, halved to beam bearer and cross-bearer as shown and well secured. The beam bearer of long deck is to be jogged 2^{in} on truss post, and supported by two 6^{in}x6^{in} stanchions similar to that already described.

The short deck is to be underplanked with oak, 3^{ft} wide, and the long deck is to be underplanked for a width of 20^{in}.

The *Capstan Bed* is to be of oak, jogged 2^{in} down on beams and chocked to under plank. The whole is to be well fastened and substantial against capstan and cavil strains.

FLOOR (*Pine*).

The space between kelson and high gunwale is to be floored over with removable sections, resting on the floor timbers, and on 1^{in}x3^{in} oak strips nailed to the side of the cross-bearers. In each panel there are to be four sections, two on inside of binding strake, 3^{ft} 6^{in} x7^{ft} 3^{in}, and two on outside of binding strake, 3^{ft} 4^{in}x 7^{ft} 3^{in}.

The *Sections* are to be made of $\frac{7}{8}^{in}$ matched stuff, clinch-nailed to three 1^{in}x8^{in} battens, one in the middle and one near each end, so placed that the battens will lie between floors.

CALKING.

The bottom, rakes, sides and curved deck are to be calked with one thread of cotton and two of best navy oakum, well tucked, so as to fill the seams, and made hard. The end decks, ways deck and platform are to be calked with two threads of cotton, well tucked, so as to fill the seams, and made hard. All calked seams are to be well payed with white lead.

MISCELLANEOUS.

All wood work above light water, exposed to the weather, except decks, is to be dressed and *painted* with two coats of "Elliott Asphaltum Paint," No. 15.

All screw bolts are to have *washers* on each end of a diameter not less than three times the diameter of bolt; if square washers are used they are to have an equivalent area.

All *Fastenings* are to avoid seams.

Fenders of oak, 4$^{\text{in}}$x10$^{\text{in}}$—5½$^{\text{ft}}$, corners and ends rounded, are to be spiked on at each main top timber, top of stanchion flush with platform.

Such *Cavils* as may be serviceable in towing to destination are to be provided.

SPECIFICATIONS

—FOR THE—

CONSTRUCTION

—OF—

BRUSH AND STONE BARGES

—FOR THE—

MISSOURI RIVER IMPROVEMENT,

UNDER THE DIRECTION OF

MAJOR CHAS. R. SUTER,
CORPS OF ENGINEERS, U. S. A.,
NO. 1351 WASHINGTON AVENUE,
ST. LOUIS, MO.

December 22nd, 1882.

SPECIFICATIONS

—FOR A—

BRUSH AND STONE BARGE.

SPECIFICATIONS No. 1 A.

This is to be a decked gunwale barge, 100^{ft} long, 25^{ft} beam, and 5^{ft} 4^{in} deep at gunwale, with a crown of $2\frac{1}{2}^{\text{in}}$; the rake at each end is to be curved and 14^{ft} long from face of head-piece, and the sheer is to be 12^{in}; there is to be a longitudinal bulkhead along the center line and a cross-bulkhead at the foot of each rake; the bottom and deck are to be planked fore and aft, and the deck is to be sheathed with pine boards laid athwartships.

The lumber is to be oak, white pine, southern yellow pine and yellow poplar, as may be specified, all of which must be sound, without loose or rotten knots, square edged and full cornered, and the yellow pine especially free of sap.

The barge is to be built as set forth in these specifications, and as shown in the accompanying drawings. All material must be of good quality, and the work must be done in a thorough and workmanlike manner, and to the satisfaction of the Superintendent.

GUNWALES.

Each gunwale is to be $5^{ft}\ 4^{in}$ deep over all and made up as follows:

One *Grub Strake* of oak, $4^{in} \text{x}\ 12^{in}$, laid flat and bent up the rake, as shown in drawing, in three lengths with plain scarfs, 3^{in} nibs, extending over four floors.

One *Floor Strake* of oak, $6^{in} \text{x}\ 10^{in}$, in two equal lengths of $45^{ft}\ 7\frac{1}{2}^{in}$, with 6^{ft} hook scarfs, $2\frac{1}{2}^{in}$ nibs and $1\frac{1}{4}^{in}$ hook.

Three *Web Strakes*, of white or yellow pine, each $12^{in} \text{x}\ 4\frac{1}{2}^{in}$, or 4^{in} thick of oak, in lengths as follows:—1st, 29^{ft}, 45^{ft} and 29^{ft}; 2d, $40^{ft}\ 3^{in}$, 45^{ft} and $21^{ft}\ 8^{in}$; and 3d, $23^{ft}\ 1^{in}$, 45^{ft} and $42^{ft}\ 10^{in}$—scarfs the same as in floor strake.

One *Beam Strake* of oak, $6^{in} \text{x}\ 10^{in}$, in lengths of $17^{ft}\ 10^{in}$, 40^{ft}, $29^{ft}\ 3^{in}$ and 31^{ft}—scarfs as in floor strake.

Two *Sheer Pieces* of oak, each 20^{ft} long back of head piece, or $20^{ft}\ 10^{in}$ including tenons, 6^{in} thick, 12^{in} deep at head piece, 3^{in} deep and jogged flush in the beam strake amidships, and curved to the sheer line on top as shown in drawing.

One *Planksheer* of oak, 4 ~~5~~$^{in} \text{x}\ 9^{in}$, in three lengths, with joints well broke over beam strake, with plain scarfs, $2\frac{1}{2}^{in}$ nibs extending over four beams, and bolted horizontally with three $\frac{1}{2}^{in}$ round drift bolts, riveted, $1\frac{1}{2}^{in}$ from lower edge.

Oak *Table Blocks*, six inches fore and aft of nibs of planksheer and top gunwale scarfs, end on, one inch thick and 8^{in} long, are to be jogged $\frac{1}{2}^{in}$ in gunwale and planksheer.

Two *Filling Pieces* of oak, one on each rake, extending from beam strake to floor strake, 11^{ft} long, $1\frac{1}{2}^{in}$ thick and 17^{in} wide at middle, in position as shown in drawing, are to be well spiked to gunwale with 20d. cut nails.

All *Gunwale Seams* are to be *outgauged* $\frac{1}{4}^{in}$ on a depth of 2^{in}.

Drift Bolts are to be of $\frac{3}{4}$in. round iron, driven as follows:—From below and two feet apart in lengths alternating 24^{in} and 36^{in}; from top edge of upper web strake, four feet apart, in lengths of 32^{in}; and from top gunwale or beam strake, two feet apart, in lengths of 30^{in} all as shown in the sheer plan.

Top-timbers of oak, 5^{in}x 6^{in} with edge to gunwale, extending from grub strake to planksheer and halved 2^{in} on floor and $\frac{1}{2}^{in}$ on beam, are to be spaced 6^{ft} apart amidships or over each butting floor-timber. The extreme ones are to carry the cross-bulkheads and each intermediate is to be braced to kelson with a 4^{in}x 6^{in} oak or yellow pine brace, bolted to top-timber with one $\frac{1}{2}^{in}$ round bolt 15^{in} long and spiked to floor with two 8^{in}x $\frac{3}{8}^{in}$ spikes; each top-timber is to be fastened to gunwale with two $\frac{3}{8}^{in}$ round bolts, riveted, to each strake and well spiked to beam and floor.

Gunwale timbers may be varied in length, provided always that the number of splices is not increased and they are equally well shifted. The widths of the three web strakes only may be varied, provided the depth of gunwale is not changed.

MAIN BULKHEAD.

The main bulkhead runs fore and aft, from head-piece to head-piece, and is to be made up as follows: An oak *kelson*, 5^{in}x 5^{in}, jogged $\frac{1}{2}^{in}$ on floor timbers, slit to springing line, 2^{in} from top edge, and bent up the rake; four strakes, $4\frac{1}{2}^{in}$x 10^{in}, of white or yellow pine or yellow poplar, and a top strake or string piece of oak, 5^{in}x 5^{in}, jogged $\frac{1}{2}^{in}$ on beams, and spiked to kelson at head-piece.

All splices are to be plain scarfs, 4^{ft} long with $1\frac{1}{2}^{in}$ nibs, and well shifted. No timber less than 30^{ft} long is to be used except to complete a strake.

Drift Bolts are to be $\frac{5}{8}^{in}$ round iron, driven as follows: At each butting floor and alternate, 22^{in} long, from below through keel plank, floor and kelson into bulkhead; down through each beam, 27^{in} long; and from top edge of 2d, 3d and 4th strake above kelson, three feet apart and 19^{in} long. The kelson is to be spiked to each floor adjacent to butting floors with one 8^{in}x$\frac{3}{8}^{in}$ spike.

Top-timbers of oak, 5^{in}x4^{in}, are to be placed over the foot of each rake, on each side of the bulkhead and opposite the gunwale top-timbers, to carry the cross-bulkheads; they are to be fitted, spiked and bolted through, the same as the gunwale top-timbers.

Chocks or filling pieces, $4\frac{1}{2}^{in}$ thick, of white or yellow pine, are to be fitted in beneath the kelson and between floors and well fastened.

FLOOR TIMBERS (*Oak*).

The floor timbers are to be 3^{in}x6^{in}, with every 4th or butting floor 4^{in}x6^{in}, spaced 18^{in} centres between cross-bulkheads and 16^{in} centres up rakes; they are to be jogged $1\frac{1}{2}^{in}$ down on grub strake and boxed into lower gunwale or floor strake, full thickness, 3^{in} on and $4\frac{1}{2}^{in}$ up; they are to be fastened at each end with a $\frac{1}{2}^{in}$ round drift bolt, 18^{in} long, driven inclined from below through grub strake as shown, and an 8^{in}x$\frac{3}{8}^{in}$ spike at edge of grub strake.

The grub strake is to be spiked to lower gunwale or floor strake with one 8^{in}x$\frac{3}{8}^{in}$ spike, opposite the end of each floor, and one in each space between floors.

The floors are to be fastened to kelson and main bulkhead as specified under the head of *Main Bulkhead.*

BEAMS (*Oak*).

The beams are to be 6^{in}x3^{in}, spaced 2^{ft} centres; they are to be jogged 1^{in} under the planksheer and boxed into top gunwale or beam strake full thickness, 3^{in} on and 5^{in} down; they are to be fastened at each end with a $\frac{1}{2}^{in}$ round drift bolt, 18^{in} long. driven inclined through planksheer as shown, and an $8^{in}\text{x}\frac{3}{8}^{in}$ spike at edge of planksheer.

The planksheer is to be spiked to gunwale or beam strake with one $8^{in}\text{x}\frac{3}{8}^{in}$ spike, opposite the end of each beam, and one in each space between beams.

The beams are to be crowned $2\frac{1}{2}^{in}$ at centre and secured to main bulkhead as specified under head of *Main Bulkhead.*

STRINGERS (*Oak*).

There are to be two binding strakes, $4^{in}\text{x}5^{in}$ on edge over floors on each side of main bulkhead; they are to be slit to springing line, 2^{in} from top edge, bent up rake and boxed into head-piece as shown; they are to be in lengths of not less than 30^{ft}, with plain scarfs over three floors, and are to be fastened to each floor with $\frac{3}{8}^{in}$ round bolts driven from below and riveted.

There is to be a deck stringer over each binding strake, $3^{in}\text{x}4^{in}$ on edge, in lengths not less than 30^{ft}, with plain scarfs over three beams, spiked to each beam with one $8^{in}\text{x}\frac{3}{8}^{in}$ spike, and spiked to binding strake at head-piece with two spikes.

STANCHIONS (*Pine or Yellow Poplar*).

The stanchions are to be $4^{in}\text{x}4^{in}$ and 4^{ft} apart, placed adjacent to alternate beams and halved to binding strakes and deck stringers, and spiked thereto. They are to be alternately on opposite sides of the string piece, and are to alternate in position with those on the adjacent string piece.

CROSS-BULKHEADS (*Dry Pine*).

A cross-bulkhead is to be placed at the foot of each rake, extending from floor timber to beam, and supported by the gunwale and main bulkhead top-timbers and by five oak or yellow pine stanchions on each side of main bulkhead, those over binding strakes to be $4^{in}x6^{in}$, and intermediates $4^{in}x4^{in}$, all fitted to floor and beam and well spiked.

The bulkhead is to be of 2^{in} by not over 6^{in} plank with seams outgauged $\frac{1}{8}^{in}$ for calking, fastened with 20^{d} cut nails, two to each stanchion and three to each butt in each plank.

Head-Piece, Etc.

The head-piece is to be of oak worked out from a piece $10^{in}x27^{in}$—25^{ft}. It is to be crowned $2\frac{1}{2}^{in}$ at middle and beveled top and bottom fair with deck and rake. It is to be rabbeted $3^{in}x3^{in}$ to receive deck and jogged across ends 6^{in} wide and 4^{in} down for planksheer, and rabbeted 7^{in} on, measured along bottom of rabbet, and $2\frac{1}{2}^{in}$ up to receive bottom and jogged across ends 6^{in} wide and 4^{in} up to receive grub strake. The binding strakes and kelson are to be boxed into square ends and, together with grub strake and planksheer, securely fastened. The ends are to be mortised to receive two 3^{in} gunwale tenons, and the corners on each side bolted with two $\frac{5}{8}^{in}$ round drift bolts, 20^{in} long.

Knees or *corner pieces* of oak, 10^{in} thick and 2^{ft} on angles, are to be fitted in each corner flush with bottom of deck.

Corner Straps of iron, $5^{in}x\frac{5}{8}^{in}$, 30^{in} long on head-piece, and 3^{ft} on gunwale, are to be let in flush, one on each corner. These straps are to have 1^{in} hooks, and are to be secured with one $\frac{3}{4}^{in}$ round screw bolt at each end and drift bolted on front with three $\frac{3}{4}^{in}$ round belts, one 16^{in} long, one 20^{in} and one 12^{in} driven through head-piece, and three side bolts, one 12^{in} long, one 16^{in} and one 12^{in}—all well shifted vertically and all heads flush with strap, substantially as shown in drawing.

A *Nozing* of oak, 3^{in}x24^{in}—25^{ft}, is to be fitted fair to face of head-piece, corners rounded, and spiked on with 6^{in} spikes.

TIMBER-HEADS (*Oak*).

The timber-heads are to be eight in number, placed in pairs, 12^{in} apart, with center of pair 9^{ft} 6^{in} from face of head-piece; they are to be 8^{in}x12^{in}, extending from rake to 12^{in} above deck and are to be let into planksheer 3^{in}, and the gunwale filled out with a $1\frac{1}{2}^{in}$ oak plank to give a full bearing; they are to be secured to gunwale with five $\frac{3}{4}^{in}$ square screw bolts on flat washers, heads flush outside.

BOTTOM (*Oak*).

The bottom planks are to be $2\frac{1}{2}^{in}$ thick, not over $15^{\text{per cent.}}$ of which are to be in lengths less than 24^{ft}, all lengths differing by 6^{ft} or the distance between butting floors, with all butts well shifted. The rake planks are to be slit to light water to widths of not over 6^{in}, and all seams are to be outgauged $\frac{1}{8}^{in}$ strong.

The bottom is to be fastened with 5^{in}x$\frac{5}{16}^{in}$ cut boat spikes, driven two to each floor and three to each butt in plank less than 14^{in} wide, and three to each floor and four to each butt in widths greater than 14^{in}.

DECK (*Dry Pine*).

The decking is to be dry white or yellow pine, 2^{in} thick, in widths not greater than 6^{in} and in lengths not less than 24^{ft} except to fill out a strake. All butts are to be well shifted, and all seams are to be outgauged $\frac{1}{8}^{in}$. The deck is to be fastened with 20d. cut nails, two to each beam and three to each butt in each plank.

Deck Sheathing of 1^{in} pine boards is to be laid athwartships, from planksheer to planksheer, over a coat of pine tar, and tacked down with $2\frac{1}{4}^{in}$ cut nails.

Hatches, four in number, are to be provided, one on each side over each cross-bulkhead, one beam space long each side of the bulkhead and 20in wide, with a combing 1½in above sheathing.

CALKING.

The deck and cross-bulkheads are to be calked with two threads of cotton, well tucked, so as to fill the seams, and made hard; the bottom, rakes and gunwales are to be calked with one thread of cotton and two of best navy oakum, well tucked, so as to fill the seams, and made hard. All calked seams are to be payed with white lead.

PUMPS.

The barge is to be provided with four box pumps not less than 3½in square, placed one back of each hatch in suitable wells, and provided with valves, rods and brakes or springpoles.

Limbers, ½inx3in, are to be cut under each floor, 6in from each grub strake.

SPECIFICATIONS NO. 1 B.

This barge is not to differ from the one already specified, except in the changes necessitated through cross-planking the bottom with 3^{in} pine plank; viz:—

GUNWALES.

The bottom strake or lower gunwale is to be of oak, 7^{in}x7^{in}, in three lengths of 16^{ft} 9^{in}, 45^{ft} 2^{in} and $33^{\text{ft}}4^{\text{in}}$, with hook scarfs 6^{ft} long, $2\frac{1}{2}^{\text{in}}$ nibs and $1\frac{1}{4}^{\text{in}}$ hook.

The second gunwale or girder strake is to be of white or yellow pine, 10^{in}x6^{in}, in two lengths of 47^{ft} 6^{in} each.

The third, fourth and fifth gunwales or web strakes are to be of white or yellow pine, $4\frac{1}{2}^{\text{in}}$x10^{in}, in the following lengths:—1st, 29^{ft} 10^{in}, 45^{ft} and 29^{ft} 10^{in}; 2nd, 40^{ft} 8^{in}, 44^{ft} 11^{in} and 22^{ft}; and 3rd, 23^{ft} 1^{in}, 45^{ft} and 42^{ft} 10^{in}—all scarfs to be same as lower gunwale, and all seams to be outgauged $\frac{1}{4}^{\text{in}}$ on a depth of 2^{in}.

The top or beam strake is to be 6^{in}x10^{in}, the sheer pieces, 6^{in} thick, and the planksheer, 4^{in}x9^{in}, all of oak and as already specified.

Drift Bolts are to be of $\frac{3}{4}^{\text{in}}$ round iron, driven as follows:—From below and two feet apart in lengths alternating 24^{in} and 36^{in}; from top edge of web or 5th strake, 4^{ft} apart, in lengths of 28^{in}, and from top of gunwale or beam strake, 2^{ft} apart, in lengths of 28^{in}—all as shown in sheer plan.

Top-timbers of oak, 6^{in}x8^{in}, flat to gunwale, extending from planksheer to bottom, are to be spaced 8^{ft} apart amidships; they are to be jogged 3^{in} over top of girders or cross-floors and well spiked thereto; they are to be bolted to gunwale with two $\frac{3}{8}^{in}$ round bolts, riveted to each strake; the timbers at the foot of the rakes are to carry the cross-bulkheads, and each intermediate is to be braced with a 4^{in}x6^{in} oak or yellow pine brace, heeled on the girder at the main bulkhead and secured with two 8^{in}x$\frac{3}{8}^{in}$ spikes, and bolted to the top-timber with one $\frac{1}{2}^{in}$ round bolt 15^{in} long, all as shown.

Gunwale timbers may be varied in length, provided always that the number of splices is not increased and they are equally well shifted. The widths of the 3rd, 4th and 5th strakes may be varied, provided the depth of gunwale is not changed.

MAIN BULKHEAD.

The *kelson* is to be of oak, 6^{in}x7^{in} on edge, in three lengths; it is to be bent up each rake in two pieces, the upper one 3^{in} thick and scarfed out to an $1\frac{1}{2}^{in}$ nib, 6^{ft} back of cross-bulkhead. The balance of the bulkhead is to be of white or yellow pine or yellow poplar, $4\frac{1}{2}^{in}$ thick, in widths of 10^{in}, 9^{in} and three 8^{in}, topped with a 5^{in}x5^{in} oak stringer, jogged $\frac{1}{2}^{in}$ on beams as already specified. All splices are to be plain scarfs, 4^{ft} long, with $1\frac{1}{2}^{in}$ nibs, and well shifted, and no timber less than 30^{ft} long is to be used except to complete a strake.

Drift Bolts are to be of $\frac{5}{8}^{in}$ round iron, driven as follows:—From below, 3^{ft} apart, in lengths of 25^{in}; from top of 3rd and 4th strake above kelson, 3^{ft} apart, in lengths of 20^{in}, and down through beams in lengths of 25^{in}.

Top-timbers of oak, 4^{in}x8^{in}, jogged 3^{in} over girders, are to be placed over the spring of each rake on each side of the main bulkhead and opposite the gunwale top-timbers to carry the cross-bulkheads; they are to be bolted through and spiked, the same as the gunwale top-timbers.

STREAMERS OR FLOOR STRINGERS (*Oak*).

The streamers or floor stringers are to be 3^{in}x7^{in} on edge, 2^{ft} centres, five on each side of main bulkhead, and of pieces not less than 30^{ft} long; the splices are to be 6^{ft} plain scarfs, 1½^{in} nibs, bolted with three ½^{in} round bolts driven from below through bottom and riveted, and all splices are to be well shifted with those of adjacent streamers. The streamers are to be slit and bent up rake or carried up in two pieces, the same as the kelson.

Limbers, ½^{in}x3^{in}, are to be cut under each streamer at each girder or cross-floor.

GIRDERS OR CROSS-FLOORS (*White or Yellow Pine*).

The girders are to be 5^{in}x10^{in} on edge, four over each rake, one at each springing line and eight amidships or eighteen in all; those over the rake are to be at right angles thereto, jogged 2^{in} down and 3^{in} on at ends to fit mortise in filling piece and gunwales; those over the springing lines and amidships are to be eight feet apart, jogged 4^{in} down and 3^{in} on at ends to fit boxes in 2d gunwale or girder strake. Each girder is to be secured at each end by one ⅝^{in} round drift bolt, driven inclined from below through gunwale and girder and riveted, and at middle by a similar bolt, driven vertically through kelson; it is also to be secured to each streamer by one ½^{in} round bolt driven from below and riveted.

The girders at foot of rakes and amidships are to be further secured by means of the top-timbers, as before described.

STANCHIONS.

Stanchions amidships are to be 4^{in}x4^{in}, of white or yellow pine, 4^{ft} apart fore and aft on each stringer line, and alternating in position on the 2d and 4th line of streamers; they are to be halved to deck stringers, adjacent to the beams, and to the streamers and spiked thereto. Over the rakes they are to be placed two on each girder on each side of main bulkhead.

Stanchions of oak or yellow pine, $2^{in}x6^{in}$, over each streamer and opposite the gunwale and main bulkhead top-timbers, are to be fitted and spiked to girder and beams, at the foot of each rake, to carry the cross-bulkheads.

Chocks of pine are to be fitted in and secured beneath the bulkhead girders and between the streamers, and the *cross-bulkheads* completed as already specified.

HEAD-PIECES (*Oak*).

Each head-piece is to be worked out of a piece $10^{in}x27^{in}$ —25^{ft}. It is to be rabbeted $3^{in}x3^{in}$ to receive deck and jogged across ends for planksheer. The kelson and streamers are to be gained in across lower edge to a depth of 4^{in}, well secured and covered with the bottom plank. The ends of deck stringers are to be boxed in to a depth of 4^{in} and well secured. Each end of the head-piece is to be mortised to receive two 3^{in} gunwale tenons and the corners bolted each side with two $\frac{5}{8}^{in}$ round drift bolts, 20^{in} long.

The *Nozing*, *Corner Straps* and *Knees* are to be substantially as already specified.

BOTTOM (*White or Yellow Pine*).

The bottom planks are to be laid athwartships, 3^{in} thick and full length of 25^{ft}, with all seams outgauged $\frac{1}{4}^{in}$. The rake planks above light water are to be of dry lumber not over 6^{in} wide.

The bottom is to be fastened with $6^{in}x\frac{5}{16}^{in}$ cut boat spike, not less than two to each streamer and three to each butt, in plank of 14$^{\text{in}}$ or less width, and three to each streamer and four to each butt for greater widths.

Except in the particulars above specified and necessitated through cross-planking the bottom, the first specification (No. 1 A) is to be followed.

SPECIFICATIONS

—FOR A—

BRUSH AND STONE BARGE.

SPECIFICATIONS No. 2 A.

This is to be a decked gunwale barge, 64^{ft} long, 16^{ft} beam and $3^{ft}\ 4^{in}$ deep at gunwale, with a crown of $2\frac{1}{2}^{in}$; the rake at each end is to be curved and 8^{ft} long from face of head-piece, and the sheer is to be 9^{in} ; there is to be a longitudinal bulkhead along the centre line, and a cross-bulkhead at the foot of each rake; the bottom and deck are to be planked fore and aft, and the deck is to be sheathed with pine boards laid athwartships.

The lumber is to be oak, white pine, southern yellow pine and yellow poplar, as may be specified, all of which must be sound, without loose or rotten knots, square edged and full cornered, and the yellow pine especially free of sap.

The barge is to be built as set forth in these specifications, and as shown in the accompanying drawings. All material must be of good quality, and the work must be done in a thorough and workmanlike manner, and to the satisfaction of the Superintendent.

GUNWALES.

Each gunwale is to be 3^{ft} 4^{in} deep over all and made up as follows:

One *Grub Strake* of oak, 3^{in}x12^{in}, laid flat and bent up the rake as shown in the drawing, in three lengths with plain scraps, 3^{in} nibs, extending over four floors.

One *Floor Strake* of oak, 5^{in}x9^{in}, in two equal lengths of 31^{ft} 2^{in}, with 6^{ft} hook scarfs, $2\frac{1}{2}^{in}$ nibs and $1\frac{1}{4}^{in}$ hook.

Two *Web Strakes*, of white or yellow pine or oak, each 8^{in}x4^{in}, in lengths as follows: 1st, 15^{ft} 9^{in}, 40^{ft} and 15^{ft} 9^{in}; 2nd, 25^{ft} 10^{in}, 21^{ft} and 26^{ft} 8^{in}—scarfs the same as in floor strake.

One *Beam Strake* of oak, 5^{in} x9^{in}, with a length of 45^{ft} amidships, and 15^{ft} 6^{in} at each end; the end timbers to be each 18^{in} wide at head piece and curved to sheer line, thus constituting the *sheer* or *rising piece*—scarfs as in floor strake.

One *Planksheer* of oak, 3^{in}x9^{in}, with joints well broke over beam strake, with plain scarfs, $2\frac{1}{2}^{in}$ nibs, extending over four beams, and bolted horizontally with three $\frac{1}{2}^{in}$ round drift bolts, riveted, $1\frac{1}{4}^{in}$ from lower edge.

Oak *Table Blocks*, six inches fore and aft of nibs of each planksheer and top gunwale scarf, end on, 1^{in} thick and 8^{in} long, are to be jogged $\frac{1}{2}^{in}$ in gunwale and planksheer.

Two *Filling Pieces* of oak, one on each rake extending from beam strake to floor strake, $4\frac{1}{2}^{ft}$ long, 1^{in} thick and 10^{in} wide at middle and curved to rake, are to be well nailed to gunwale.

All *Gunwale Seams* are to be outgauged $\frac{1}{4}^{in}$ on a depth of 2^{in}.

Drift Bolts are to be of $\frac{3}{4}^{in}$ round iron, driven as follows: From below, three feet apart, in lengths of 19^{in}, and from top gunwale or beam strake, two feet apart, in lengths of 30^{in} —all as shown in the sheer plan.

Top-timbers of oak, 5^{in}x5^{in}, extending from grub strake to planksheer and halved 2^{in} on floor and $\frac{1}{2}^{in}$ on beam, are to be spaced 6^{ft} apart amidships or over each butting floor-timber. The extreme ones are to carry the cross bulkheads and each intermediate is to be braced to kelson with a 4^{in}x5^{in} oak or yellow pine brace, bolted to top-timber with one $\frac{1}{2}^{in}$ round bolt 15^{in} long and spiked to floor with two 8^{in}x$\frac{3}{8}^{in}$ spikes; each top-timber is to be fastened to gunwale with two $\frac{3}{8}^{in}$ round bolts, riveted, to each strake and well spiked to beam and floor.

Gunwale timbers may be varied in length, provided always that the number of splices is not increased and they are equally well shifted.

MAIN BULKHEAD.

The main bulkhead runs fore and aft from head-piece to head-piece, and is to be made up as follows:—An oak *kelson*, 5^{in}x5^{in}, jogged $\frac{1}{2}^{in}$ on floor timbers, slit to springing line, 2^{in} from top edge, and bent up rake; three strakes, 4^{in}x6^{in}, of white or yellow pine or yellow poplar, and a top strake or string piece of oak, 5^{in}x5^{in}, jogged $\frac{1}{2}^{in}$ on beams and spiked to kelson at head-piece.

All splices are to be plain scarfs, 4^{ft} long with $1\frac{1}{2}^{in}$ nibs, and well shifted. No timber less than 24^{ft} long is to be used except to complete a strake.

Drift Bolts are to be $\frac{5}{8}^{in}$ round iron, driven as follows:—At each butting floor and alternate, 17^{in} long, from below through keel plank, floor and kelson into bulkhead; down through each beam, 21^{in} long; and from top of web, 3^{ft} apart and 21^{in} long. The kelson is to be spiked to each floor adjacent to butting floors with one 8^{in}x$\frac{3}{8}^{in}$ spike.

Top-timbers of oak, 5^{in}x3^{in}, are to be placed over the foot of each rake, on each side of the bulkhead and opposite the gunwale top-timbers, to carry the cross-bulkheads; they are to be fitted, spiked and bolted through, the same as the gunwale top-timbers.

Chocks or filling pieces, 4^{in} thick, of white or yellow pine, are to be fitted in beneath the kelson and between floors and well fastened.

FLOOR TIMBERS (*Oak*).

The floor timbers are to be 3^{in}x5^{in}, with every 4th or butting floor 4^{in}x5^{in}, spaced 18^{in} centres between cross-bulkheads and 16^{in} centres up rakes; they are to be jogged $\frac{1}{2}^{in}$ down on grub strake and boxed into gunwale floor strake, full thickness, $2\frac{1}{2}^{in}$ on and $4\frac{1}{2}^{in}$ up; they are to be fastened at each end with a $\frac{1}{2}^{in}$ round drift bolt, 16^{in} long, driven inclined from below through grub strake as shown, and a 7^{in}x$\frac{5}{16}^{in}$ spike at edge of grub strake.

The grub strake is to be spiked to lower gunwale or floor strake with one 7^{in}x$\frac{5}{16}^{in}$ spike, opposite the end of each floor, and one in each space between floors.

The floors are to be fastened to kelson and main bulkhead as specified under the head of *Main Bulkhead.*

BEAMS (*Oak*).

The beams are to be 5^{in}x3^{in}, spaced 2^{ft} centres; they are to be boxed into upper gunwale or beam strake full size and $2\frac{1}{2}^{in}$ on; they are to be fastened at each end with a $\frac{1}{2}^{in}$ round drift bolt, 16^{in} long, driven inclined through planksheer as shown, and a 7^{in}x$\frac{5}{16}^{in}$ spike at edge of planksheer.

The planksheer is to be spiked to top gunwale or beam strake with one 7^{in}x$\frac{5}{16}^{in}$ spike, opposite the end of each beam, and one in each space between beams.

The beams are to be crowned $2\frac{1}{2}^{in}$ at centre and secured to main bulkhead as specified under head of *Main Bulkhead.*

STRINGERS (*Oak*).

There is to be one binding strake, 4^{in}x5^{in} on edge, over floors on each side of main bulkhead, to be slit 2^{in} from top edge, and bent up rake and boxed into head-piece as shown; it is to be in not over three lengths with plain scarfs over three floors, and is to be fastened to each floor with a $\frac{3}{8}^{in}$ round bolt driven from below and riveted.

There is to be a deck stringer over each binding strake, 3^{in}x4^{in} on edge, in not over three lengths, with plain scarfs over three beams, spiked to each beam with one 8^{in}x$\frac{3}{8}^{in}$ spike and spiked to binding strake at head-piece with two spikes.

STANCHIONS (*Pine or Yellow Poplar*).

The stanchions are to be 4^{in}x4^{in}, 2^{ft} apart or adjacent to beams, and halved to binding strake and deck stringer, and spiked thereto.

CROSS-BULKHEADS (*Dry Pine*).

A cross-bulkhead is to be placed at the foot of each rake, extending from floor timber to beam, and supported by the gunwale and main bulkhead top-timbers and by three oak or yellow pine stanchions on each side of main bulkhead, 4^{in}x4^{in}, fitted to floors and beam and well spiked.

The bulkhead is to be of 2^{in} by not over 6^{in} plank, with seams outgauged $\frac{1}{8}^{in}$ for calking, fastened with 20^{d} cut nails, two to each stanchion and three to each butt in each plank.

HEAD-PIECE, ETC.

The head-piece is to be of oak, worked out from a piece 8^{in}x$20\frac{1}{2}^{in}$—16^{ft}. It is to be crowned $2\frac{1}{2}^{in}$ at middle and beveled top and bottom, fair with deck and rake. It is to be rabbeted 3^{in}x3^{in} to receive deck and jogged across ends 5^{in} wide to receive planksheer, and rabbeted 5^{in} on, measured along bottom of rabbet, and $2\frac{1}{2}^{in}$ up to receive bottom, and jogged across ends 5^{in} wide and 3^{in}up to receive grub strake. The binding strakes and kelson are to be boxed in to square ends and, together with grub strake and planksheer, securely fastened. The ends are to be mortised to receive the gunwale as shown, and the corners on each side bolted with two $\frac{5}{8}^{in}$ round bolts 18^{in} long.

Knees or *corner pieces* of oak, 8^{in} thick and 14^{in} on angles, are to be fitted in each corner flush with bottom of deck.

Corner Straps of iron, 4^{in}x$\frac{1}{2}^{in}$, 2^{ft} long on head-piece and 30^{in}on gunwale, are to be let in flush, one on each corner. These are to have 1^{in} hooks and are to be secured with one $\frac{3}{4}^{in}$ round screw bolt at each end and drift bolted on front with three $\frac{3}{4}^{in}$ round bolts, one 14^{in} long and two 16^{in}, and three side bolts, 12^{in} long—all well shifted vertically and all heads flush with strap.

A *Nozing* of oak, 3^{in}x17^{in}—16^{ft} is to be fitted fair to face of head-piece, corners rounded, and spiked on with 6^{in} spike.

TIMBER-HEADS (*Oak*).

The timber-heads are to be eight in number, placed in pairs, 11^{in} apart, with centre of pair 4^{ft} 4^{in} from face of head-piece; they are to be 6^{in}x10^{in}, extending from rake to 12^{in} above deck, and are to be let into planksheer 4^{in} and the gunwale filled out with an inch plank to give a full bearing; they are to be fastened to gunwale with three $\frac{3}{4}^{in}$ square screw bolts on flat washers, heads flush outside.

BOTTOM (*Oak*).

The bottom planks are to be $2\frac{1}{2}^{in}$ thick, not over 20 per cent of which are to be in lengths less than 24^{ft}, all lengths differing by six feet or the distance between butting floors, with all butts well shifted. The rake plank are to be slit to light water to widths of not over 6^{in}, and all seams are to be outgauged $\frac{1}{8}^{in}$ strong.

The bottom is to be fastened with $5^{in}x\frac{5}{16}^{in}$ cut boat spikes, driven two to each floor and three to each butt in plank less than 14^{in} wide, and three to each floor and four to each butt in widths greater than 14^{in}.

Deck (*Dry Pine*).

The decking is to be dry white or yellow pine, 2^{in} thick, in widths not greater than 6^{in}, and in lengths not less than 22^{ft}, except to fill out a strake. All butts are to be well shifted and all seams are to be outgauged $\frac{1}{8}^{in}$. The deck is to be fastened with 20^{d} cut nails, two to each beam and three to each butt in each plank.

Deck Sheathing of 1^{in} pine boards is to be laid athwartships, from planksheer to planksheer, over a coat of pine tar and tacked down with $2\frac{1}{4}^{in}$ cut nails.

Hatches, four in number, are to be provided, one on each side over each cross-bulkhead, one beam space long each side of the bulkhead and 20^{in} wide, with a combing $1\frac{1}{2}^{in}$ above sheathing.

Calking.

The deck and cross-bulkheads are to be calked with two threads of cotton, well tucked, so as to fill the seams, and made hard; the bottom, rakes and gunwales are to be calked with one thread of cotton and two of best navy oakum, well tucked, so as to fill the seams, and made hard. All calked seams are to be payed with white lead.

Pumps.

The barge is to be provided with four box pumps not less than $3\frac{1}{2}^{in}$ square, placed one back of each hatch in suitable wells and provided with valves, rods and brakes or spring-poles.

Limbers, $\frac{1}{2}^{in}$x3^{in}, are to be cut under each floor, 6^{in} from each grub strake.

SPECIFICATIONS No. 2 B.

This barge is not to differ from the one already specified, except in the changes necessitated through cross-planking the bottom with 3^{in} pine plank; viz.:

GUNWALES.

The bottom strake or lower gunwale is to be of oak, 6^{in}x6^{in}, in two equal lengths of $30^{ft}\ 5^{in}$, with hook scarfs, 6^{ft} long, $2\frac{1}{2}^{in}$ nibs and $1\frac{1}{4}^{in}$ hook.

The second gunwale or girder strake is to be of white or yellow pine, 5^{in}x9^{in}, in lengths as follows: $15^{ft}\ 5^{in}$, 40^{ft} and $15^{ft}\ 5^{in}$.

The third strake is to be of white or yellow pine, 4^{in}x10^{in}, in lengths as follows: $25^{ft}\ 10^{in}$, 21^{ft} and $26^{ft}\ 8^{in}$.

All scarfs to be same as lower gunwale, and all seams outgauged $\frac{1}{4}^{in}$ on 2^{in} .

The fourth or beam strake, 5^{in}x9^{in}, and the planksheer 3^{in}x9^{in}, to be of oak and as already specified.

Drift Bolts are to be of $\frac{3}{4}^{in}$ round iron, driven as follows: From below, three feet apart, in lengths of 24^{in}, and from top of beam strake, two feet apart, in lengths of 24^{in}.

Top-timbers of oak, 5^{in}x6^{in}, flat to gunwale, are to be spaced 8^{ft} apart amidships and jogged 2^{in} over top of girders or cross-floors and well spiked thereto; they are to be bolted to gunwale with two $\frac{3}{8}^{in}$ round bolts, riveted, to each stake.

Gunwale timbers may be varied in length, provided always that the number of splices is not increased and they are equally well shifted.

Main Bulkhead.

The kelson is to be of oak, $5^{in}x6^{in}$ on edge, in two lengths, slit to springing line and bent up rake; the balance of bulkhead is to be of white or yellow pine or yellow poplar, 4^{in} thick, in widths of 8^{in}, 7^{in} and 6^{in}, topped with a $5^{in}x5^{in}$ oak stringer, jogged $\frac{1}{2}^{in}$ on beams as already specified. All splices are to be plain scarfs, 4^{ft} long with $1\frac{1}{2}^{in}$ nibs, and well shifted, and no timber less than 24^{ft} long is to be used except to complete a strake.

Drift Bolts are to be of $\frac{5}{8}^{in}$ round iron driven as follows: From below, 3^{ft} apart, in lengths of 18^{in}; from top of 3^{d} strake above kelson, 3^{ft} apart, in lengths of 18^{in}, and down through each beam in lengths of 21^{in}.

Top-timbers of oak, $3^{in}x6^{in}$, are to be placed at the foot of each rake on each side of the main bulkhead and opposite the gunwale top-timbers to carry the cross-bulkhead; they are to be bolted through and spiked the same as the gunwale top-timbers.

Streamers or Floor Stringers (*Oak*).

The streamers are to be $3^{in}x6^{in}$ on edge, 2^{ft} centers, three on each side of main bulkhead, and of pieces not less than 24^{ft} long; the splices are to be 6^{ft} plain scarfs, $1\frac{1}{2}^{in}$ nibs, bolted with three $\frac{1}{2}^{in}$ round bolts driven from below through bottom and riveted; and all splices are to be well shifted with those of adjacent streamers. The streamers are to be slit and bent up rake the same as the kelson. Limbers, $\frac{1}{2}^{in}x3^{in}$, are to be cut under each streamer at each girder or cross-floor.

Girders or Cross-Floors (*White or Yellow Pine*).

The girders are to be $4^{in}x8^{in}$ on edge, three over each rake at right angles thereto, one at each springing line and five amidships, 8^{ft} apart, or thirteen in all; they are to be jogged at ends, 3^{in} down and $2\frac{1}{2}^{in}$ on to fit boxes in gunwale. Each girder is to be secured at each end by one $\frac{5}{8}^{in}$ round drift bolt driven inclined from below through gunwale and riveted, and at the middle by a similar bolt driven vertically through kelson; it is also to be secured to each streamer by one $\frac{1}{2}^{in}$ round bolt driven from below and riveted.

The girders at foot of rakes and amidships are to be further secured by means of the top-timbers, as before described.

Stanchions.

Stanchions amidships are to be 4^{in}x4^{in}, of white or yellow pine, 4^{ft} apart in one row on each side of main bulkhead; they are to be halved and spiked to deck stringer at top, and to girders and middle streamer between girders at foot. Over the rakes they are to be placed one over each girder or cross-floor.

Stanchions of oak or yellow pine, 2^{in}x6^{in}, over each streamer and opposite the gunwale and main bulkhead top-timbers, are to be fitted and spiked to girder and beam, at foot of each rake, to carry the cross-bulkheads.

Chocks of pine will be fitted in and secured beneath the bulkhead girders and between the streamers, and the *cross-bulkheads* completed as already specified.

Head-Pieces (*Oak*).

Each head-piece is to be worked out from a piece 8^{in}x20^{in}—16^{ft}. It is to be rabbeted, 3^{in}x3^{in}, to receive deck and jogged across ends for planksheer. The kelson and streamers are to be gained in across lower edge to a depth of 3^{in}, well secured and covered with the bottom plank. The ends of the deck stringers are to be boxed into a depth of 3^{in} and well secured. Each end of the head-piece is to be mortised to receive the gunwale as shown, and the corners each side bolted with two $\frac{5}{8}^{in}$ round bolts, 18^{in} long.

The *Nozing*, *Corner Straps* and *Knees* are to be substantially as already specified.

BOTTOM (*White or Yellow Pine*).

The bottom planks are to be laid athwartships, 3^{in} thick and full length of 16^{ft}, with all seams outgauged $\frac{1}{4}^{in}$. The rake planks above light water are to be of dry lumber not over 6^{in} wide.

The bottom is to be fastened with $6^{in} x \frac{5}{16}^{in}$ cut boat spike, not less than two to each streamer and three to each butt in plank of 14^{in} or less width, and three to each streamer and four to each butt for greater widths.

Except in the particulars above specified and necessitated through cross-planking the bottom, the first specification (*No. 2 A*) is to be followed.